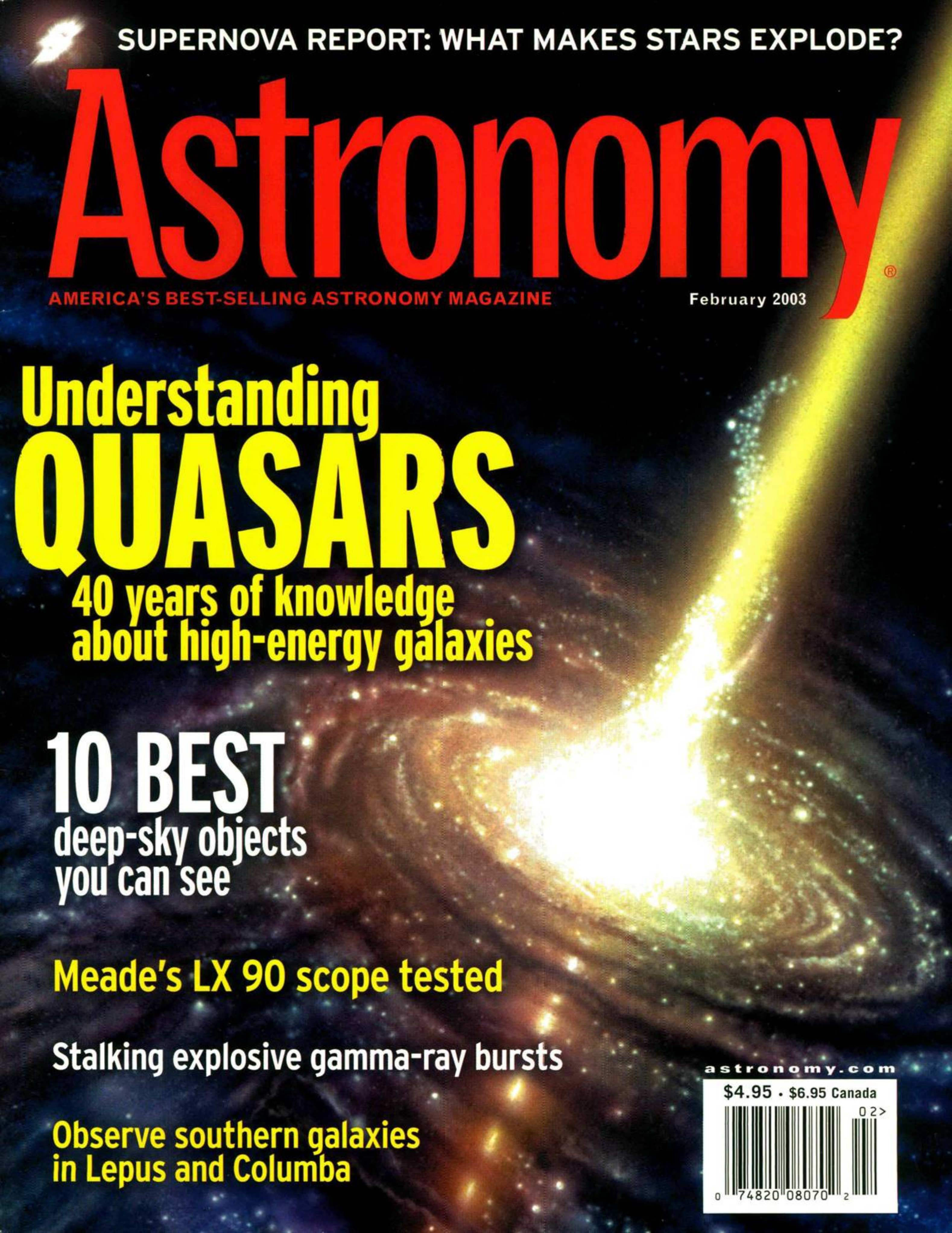

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February 2003

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The largest-selling serious telescopes in the world: Meade LX90 and LX200GPS Schmidt-Cassegrains.

In virtually every country in the world where serious telescopes are sold, more Meade LX90 and LX200GPS Schmidt-Cassegrains are sold than all competing models *combined.* In fact, leading telescope dealers report that Meade 8", 10", 12" and 14" Schmidt-Cassegrains now outsell competing Schmidt-Cassegrains *by more than three to one.*

The reasons for this overwhelming acceptance of Meade LX90 and LX200GPS telescopes are clear: advanced technology at the very leading edge of telescope design and including the patented Autostar control system; legendary diffraction-limited optical systems with optionally-available ultra-high transmission coatings; and uncanny 1-arcminute High-Precision Pointing in the GO TO mode that positions objects on even the smallest CCD chips.

Little wonder that, by any comparison, Meade LX90 and LX200GPS Schmidt-Cassegrains are the telescopes chosen by advanced amateurs worldwide for their visual, photographic, and CCD applications.

8" LX90	*reg.* $1695;	*now* **$1495;**	*save* **$200**
8" LX200GPS	*reg.* $2495;	*now* **$1995;**	*save* **$500**
10" LX200GPS	*reg.* $2995;	*now* **$2495;**	*save* **$500**
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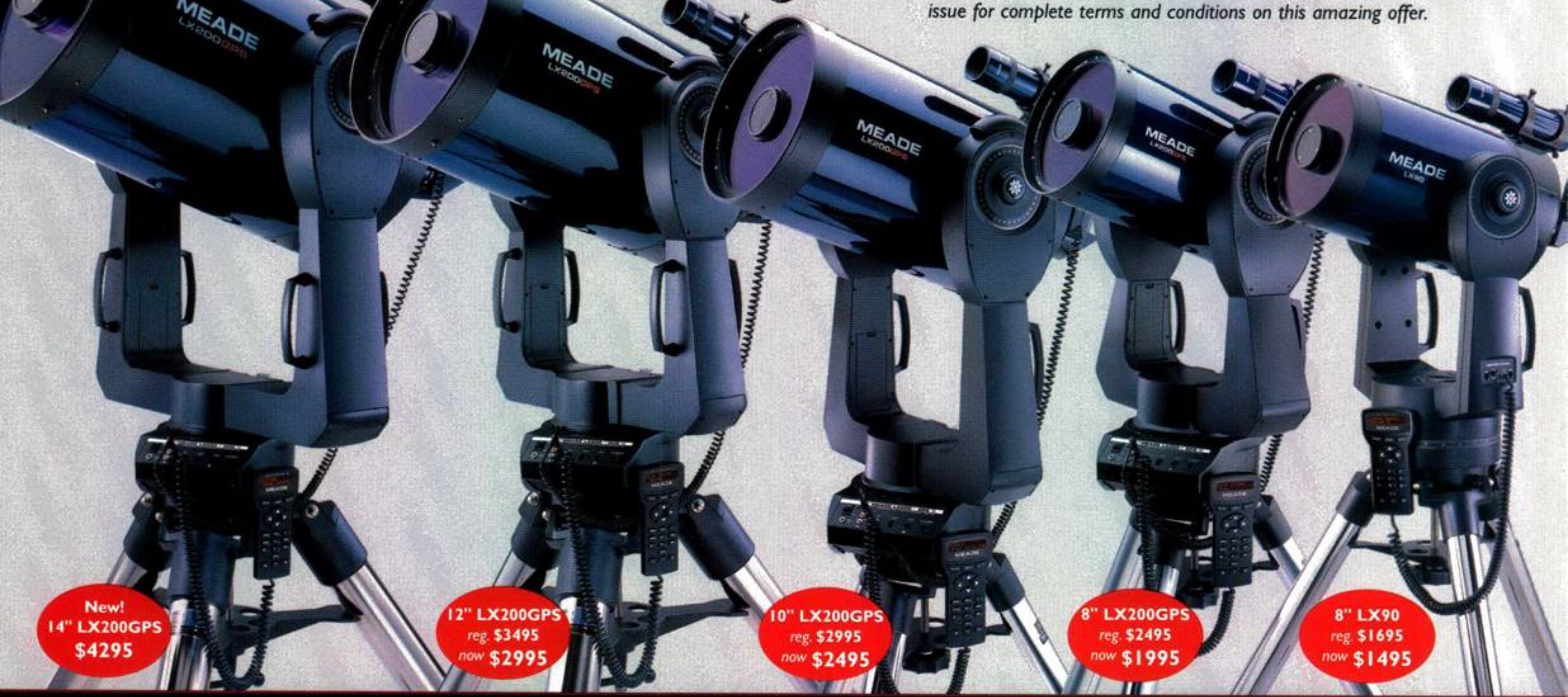
7" LX200GPS	*reg.* $2995;	*now* **$2495;**	*save* **$500**

Ultra-High Transmission Coatings (UHTC) group: 8" LX90 or 8" LX200GPS – $175; 10" LX200GPS – $235; 12" LX200GPS – $295; 14" LX200GPS – $350; 7" LX200GPS Maksutov-Cassegrain – $150.

Packing & shipping charges in the 48 states: 8" LX90 – $95; 8" LX200GPS – $105; 10" – $145; 12" – $215; 14" – $265; 7" – $125. Prices shown are suggested U.S. national mail-order retail prices. Certain Meade telescopes and Autostar control systems are manufactured under U.S. Patent Nos. 6,304,376 and 6,392,799; other patents pending in the U.S.A. and worldwide. Special LX90 and LX200GPS prices are valid for purchases from authorized Meade dealers in the U.S.A. **between September 15, 2002 - February 28, 2003.**

Buy a $650 Super Plössl eyepiece set for your LX90 or LX200GPS for only $99!

Through February 28, 2003, you can buy a full set of Meade premium-grade Series 4000 Super Plössl eyepieces, packed in a Meade #771 aluminum carrying case, for only **$99** with the purchase of a Meade LX90 or LX200GPS telescope. *See the Meade ad on the back-cover of this issue for complete terms and conditions on this amazing offer.*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KHAN SCOPE CENTRE, Toronto, Ontario, Canada
Orders & Information: 416-783-4140.

DPM Library

A Comparison of GPS Schmidt-Cassegrain Telescopes

	Meade LX200GPS	**Competing 8" and 11" GPS**
Primary Mirror Lock	Yes; standard equipment. Cancels residual mirror shift during visual, photographic, or CCD imaging applications	No
Zero Image-Shift Microfocuser	Yes; standard equipment. Operates from Autostar II handbox and permits 4-speed microfocusing, while maintaining precise image centration during CCD imaging	No; must be purchased separately from an alternate supplier at a cost of approx. $200 to $300
Download of Software Revisions	Yes; the latest software version, as well as custom and updated guided tours, comet and asteroid positions, may be downloaded in minutes, and at no charge, from the Meade website	No
Software Download, Automatic GO TO, and Automatic Tracking of Earth Satellites	Yes; current earth satellite orbital data (including International Space Station, Space Shuttle, etc.) may be downloaded; telescope then automatically acquires and tracks satellite at correct tracking rate	No
True-Level Tripod Sensor	Yes; automatically compensates to a precision of 10-arcminutes for user error in leveling tripod during GPS alignment	No; absence of true-level sensor requires user to precisely level the tripod **manually**. Mis-leveling of the tripod by user results in alignment star errors of up to 5° or more during GPS alignment
Maximum Slew Speed	8° per second	3° per second
Time Required to Perform a 120° Slew	15 seconds	40 seconds
Drive Speeds, each axis	185 speeds, from 0.01x sidereal to 8° per second	9 speeds, from 0.5x sidereal to 3° per second
Tracking Rates	sidereal, lunar, or custom-selected from 2000 rates	sidereal, lunar, or solar
Celestial Object Database	147,541 objects	40,000 objects
High-Precision Pointing Mode	Yes; permits GO TO pointing precision within 1-arcminute	No
Flash Memory	3.5-Meg	1.0-Meg
Permanent Periodic Error Correction	Yes, both axes	One axis only; second axis unprogrammable
Encoder Resolution	0.14 arcsecs	0.26 arcsecs
Internal Battery Compartments for cordless powering	Yes; user-supplied C-cell batteries located inside the fork arms negate any need for external power cords. (If desired, telescopes may alternately be powered by external cord.)	No
Multi-Coated Correcting Plate	Included with optional UHTC; increases light transmission by about 2% and reduces internal tube reflections	Not included and not available as an option
Enhanced Optical Coatings	Optional UHTC group results in light transmission **greater than 85%** at **all** wavelengths between 450nm - 700nm and transmission of **90% to 94%** at wavelengths between 540nm - 690nm, a range which includes the important Hα line at 656nm	Competing 11" coatings have a **peak** transmission of 85% at 510nm; **light transmission at all other visual wavelengths, including the Hα line, is below 85%**
Hand-Matched Optics	Yes; since their inception in 1980 all Meade Schmidt-Cassegrain optics have been individually hand-matched. Individual match-figuring is performed on the large correcting plate, resulting in a smooth optical figure	Yes; individual matching is performed on the small secondary mirror
Primary Mirrors	Oversize diameters (8.25" on 8" LX200GPS; 10.38" on 10" LX200GPS; 12.38" on 12" LX200GPS) result in significantly increased edge-of-field illumination	Mirror diameters (8" telescope includes 8.1" mirror; 11" includes 11.1" mirror) result in lower edge-of-field illumination
GPS Antenna	Omnidirectional, located squarely on top of fork arm; GPS signals are receivable through a larger sky-area	Omnidirectional, but location at approx. 45° angle inside fork arm results in approx. 45° sky-area being inaccessible to GPS signals
Field Tripods	8" and 10" tripods include 2"-dia. chromed steel legs; 12" and 14" tripods include 3"-dia. chromed steel legs; all tripods include a **cast aluminum** leg-lock spreader bar	8" and 11" tripods include 2"-dia. painted steel legs and a **plastic** leg-lock spreader bar
Polar Axis Bearings	1 x 4" dia. ball bearing and 1 x 2.25" dia. ball bearing mounted coaxially to the polar axis. Both bearings contribute to radial and axial stiffness	1 x 1.88" dia. roller bearing mounted coaxial to the polar axis and 3 x 0.88" dia. ball bearings rolling on an unshielded aluminum track. Only the 1.88" bearing contributes to radial stiffness
Full swing-through of optical tube in fork arms	Yes; telescope can observe 100% of sky area	Yes; telescope can observe 100% of sky area
FCC (U.S.A.) and CE (Europe) certified for low electromagnetic interference	Each telescope carries a label confirming FCC and CE certifications	Telescopes do not carry any labels confirming domestic or foreign certifications

Comparisons are based on current Meade LX200GPS models and on competitive telescopes and user manuals received in 11/2002.

New 2002 - 2003 Meade General Catalog!

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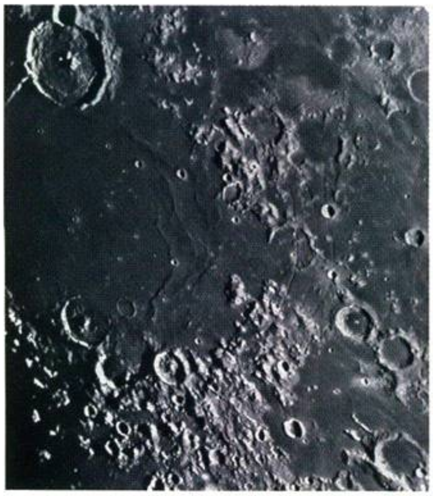

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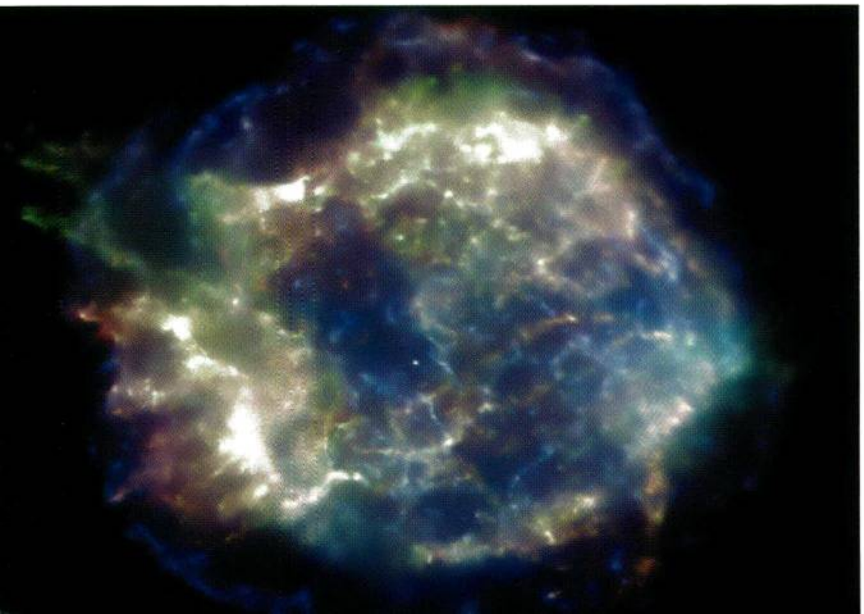

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BEHIND THE SCENES

BY DAVID J. EICHER

New Faces, New Magazine

Astronomy has a new editorial team. We are positioned to bring you a new magazine. These are exciting times in our office, and we want to tell you about them. First, our new team members: Managing Editor Patricia Lantier is a native of Lafayette, Louisiana, holds a Ph.D. in English from Marquette University, and is a veteran with more than a decade of production expertise as Editorial Director of a book publishing company. She has taught American and British literature and is well versed in science coverage from a multitude of book series. A master of communication, Pat brings valuable experience to her role as a leader of our editorial staff at *Astronomy*.

Patricia Lantier

We also welcome Associate Editor Pamela L. Gay, a freshly minted Ph.D. in galaxy cluster studies from the University of Texas in Austin. Her wide-ranging experience includes vast knowledge of the science and hobby of astronomy as well as science writing and communication. A native of the Boston area, Pamela has taught astronomy and written about the science of astronomy extensively, and will bring her expertise with amateur telescopes to future product reviews. She is also an accomplished graphic artist.

Pamela L. Gay

Astronomy also brings Matthew Quandt to the team as Editorial Intern. Matthew is an English major who was graduated from Marquette University last year. He brings an enthusiastic, energetic spirit to all manner of projects. You will see the results of his efforts throughout *Astronomy* over the coming months.

We are thrilled to have Pat, Pamela, and Matt here at *Astronomy*.

* * *

We are about to unveil a new *Astronomy*. Over the past several months our staff has talked extensively with amateur astronomers and heard an earful about what you would most like to see in the magazine. Beginning next month, you will see an *Astronomy* loaded with sharper science coverage and greatly expanded hobby stories. We will focus on giving you the best, most dazzling, up-to-the-minute scientific results on the solar system, the Milky Way, and galaxies and cosmology beyond.

Astronomy: James Forbes

Matthew Quandt

You will see far more variety and regularity of stories on observing and how-to articles, as well as expanded coverage of telescopes and equipment, and regular pieces on conventional film, digital imaging, and techniques. You will see brand-new features and departments. We are certain that you'll like the expanded, sharpened *Astronomy*. Please let me know what you think — whether I see you at a star party this coming year or whether you snail mail or e-mail me (editor@astronomy.com). I'm excited and proud to be entering a new era with you as a reader — one that will be more colorful, exciting, informative, and entertaining than ever before.

Yours truly,

Dave Eicher
Editor

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Meade ETX telescopes are the largest-selling modern telescopes in the world, with hundreds of thousands of ETX's now in the field. And every one with the unique ETX trademarks: matchless diffraction-limited optical performance; ultra-portable, contemporary design; and revolutionary Autostar GO TO capability. *See the Meade General Catalog for full details.*

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#497 Autostar controller for ETX-90EC, ETX-105EC, or ETX-125EC	**149**

Ultra-High Transmission Coatings (UHTC) group increases image brightness by about 20%: ETX-90EC– $50; ETX-105EC– $75; ETX-125EC– $95

Prices shown are suggested U.S. mail-order retail prices.

Buy a $650 Super Plössl eyepiece set for your ETX for only $99!

Through February 28, 2003, buy a full set of Meade premium-grade Series 4000 Super Plössl eyepieces, packed in a Meade #771 aluminum carrying case, for only **$99** with the purchase of any Meade ETX-90EC, -105EC, or -125EC telescope.

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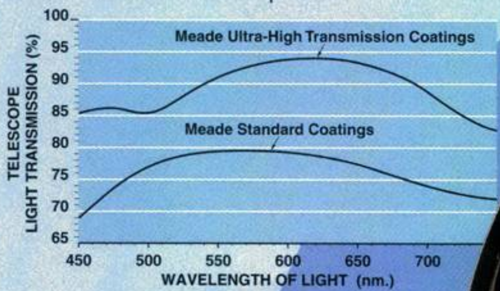
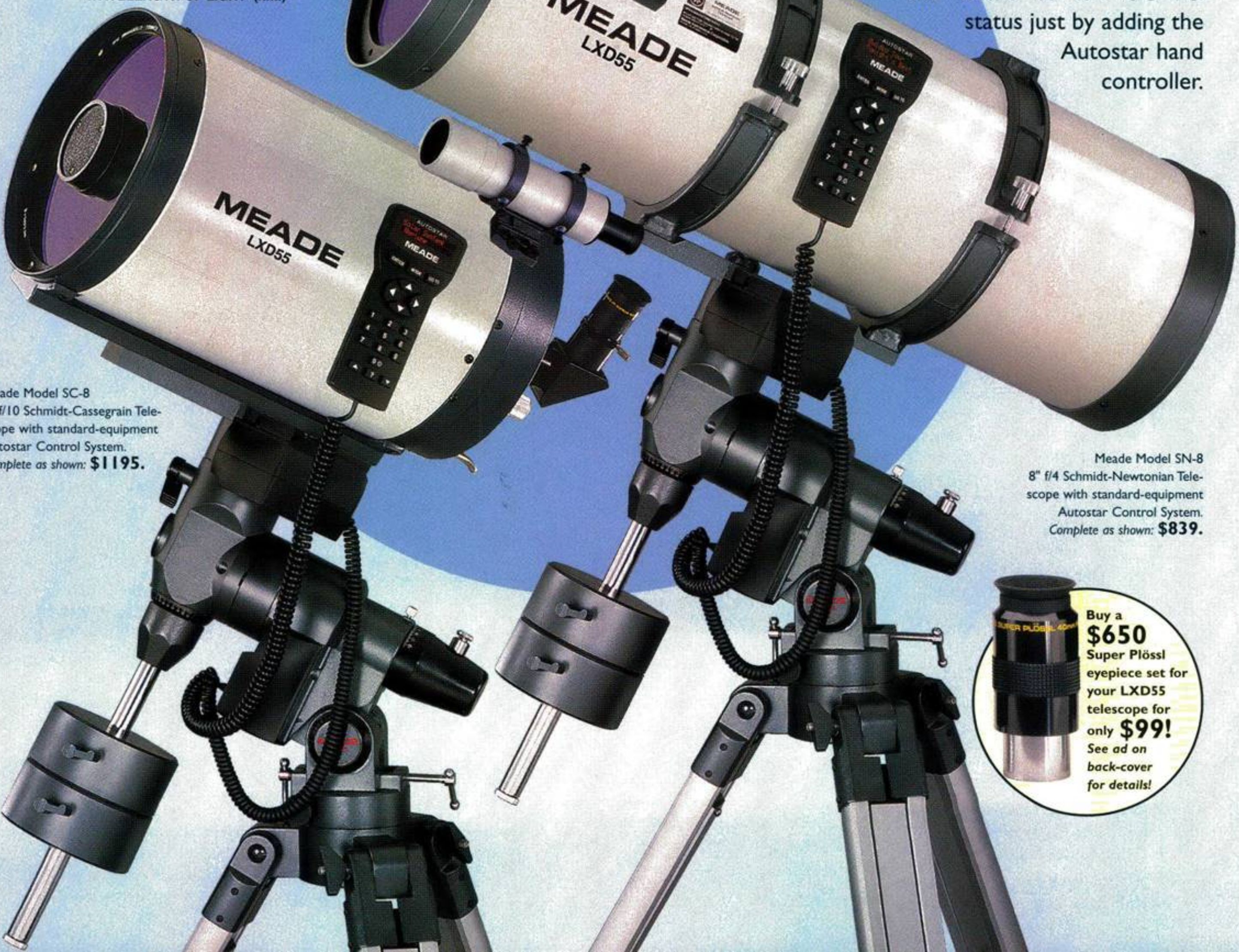
Choose from nine Meade Schmidt-Newtonians, Schmidt-Cassegrain, and Achromatic Refractors, each with Autostar® or Electronic Controller — from **$579**, *complete!*

Meade Ultra-High Transmission Coatings (UHTC) Group: Available optionally at the time of telescope purchase, the UHTC group increases image brightness by about 20% over the visible spectrum.



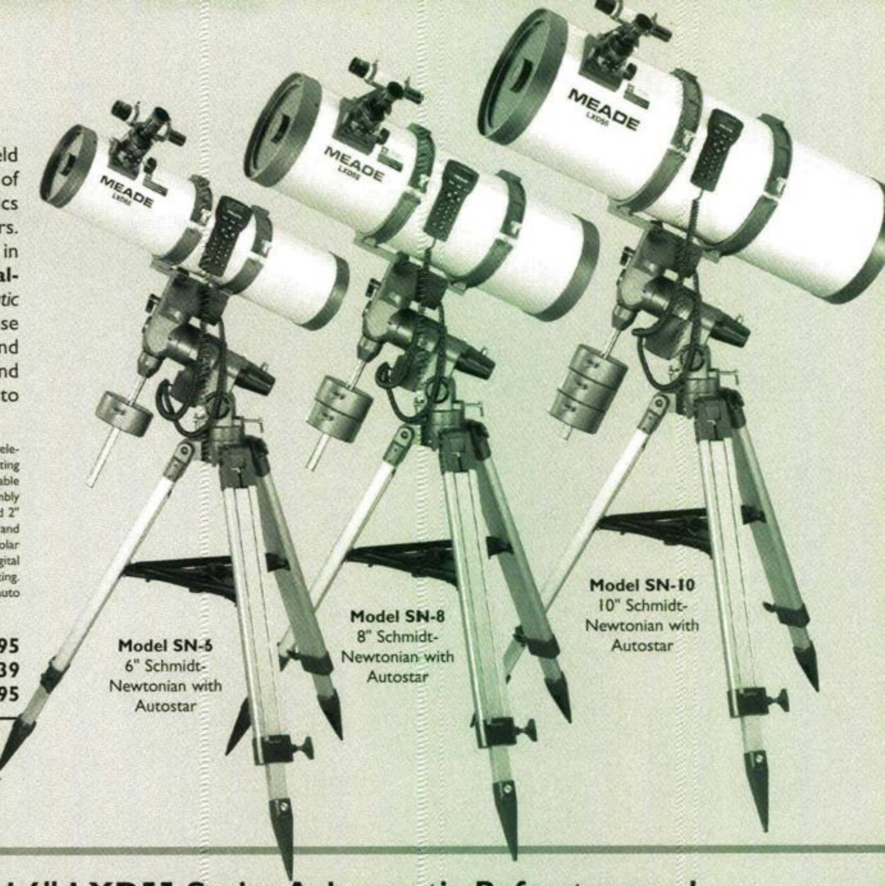
Observe ***hundreds*** of galaxies, nebulae, and star clusters of all types ***your very first night out,*** and hundreds more the next night out, simply by pressing the Autostar GO TO pushbutton. Watch as the telescope fast-slews at 4.5°/second, locating each object — from the brightest to the most obscure — and placing it automatically, unerringly, and precisely in the telescopic field. Or choose one of the new EC-models with dual-axis Electronic Controller, telescopes upgradable at any time in the future to full GO TO status just by adding the Autostar hand controller.



Meade Model SC-8
8" f/10 Schmidt-Cassegrain Telescope with standard-equipment Autostar Control System.
Complete as shown: **$1195.**

Meade Model SN-8
8" f/4 Schmidt-Newtonian Telescope with standard-equipment Autostar Control System.
Complete as shown: **$839.**

Buy a $650 Super Plössl eyepiece set for your LXD55 telescope for only $99!
See ad on back-cover for details!


Model SN-6
6" Schmidt-Newtonian with Autostar
Model SN-8
8" Schmidt-Newtonian with Autostar
Model SN-10
10" Schmidt-Newtonian with Autostar

6", 8", and 10" LXD55-Series Schmidt-Newtonians with Autostar

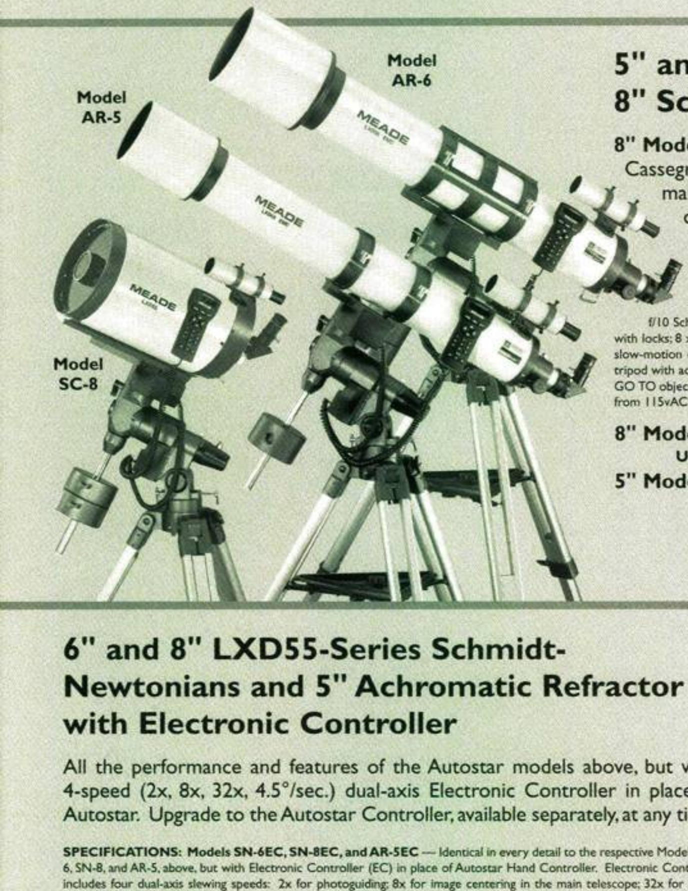
Meade American-made diffraction-limited Schmidt-Newtonian optics yield pinpoint stellar images over extremely wide fields, with *one-half* the coma of paraboloids of the same focal ratios. Fast f/4 (8", 10") or f/5 (6") optics present brilliant, rich-field imaging of nebulae, galaxies, and star clusters. High-power lunar and planetary images reveal subtle detail often lost in telescopes of lesser resolution. The standard-equipment **Autostar Dual-Axis Control System** permits an amazing range of operations: *automatic GO TO capability* at 4.5°/second to 30,223 database objects (galaxies; diffuse and planetary nebulae; star clusters; the complete Messier, Caldwell, IC, and NGC catalogs; double and variable stars; eight major planets; asteroids; and comets); *nine selectable slew and slow-motion speeds* from 1x sidereal to 4.5°/sec.; plus *automatic sidereal-rate tracking* in RA, and much more.

SPECIFICATIONS: Models SN-6, SN-8, and SN-10 Schmidt-Newtonian Telescopes — Each complete telescope includes 6" f/5, 8" f/4, or 10" f/4 Schmidt-Newtonian optical tube assembly with MgF_2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally); white-enameled metal optical tube with machined-aluminum mirror cell; quick-release cradle ring assembly with locks; 6 x 30mm achromatic viewfinder; metal rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces; Series 4000 Super Plössl 26mm eyepiece. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12v DC auto cigarette lighter plug or from 115v AC home outlet); operating instructions.

6" Model SN-6 Schmidt-Newtonian	**$695**
8" Model SN-8 Schmidt-Newtonian	**839**
10" Model SN-10 Schmidt-Newtonian	**995**

Ultra-High Transmission Coatings (UHTC) group: 6" Model SN-6 – $85; 8" Model SN-8 – $125; 10" Model SN-10 – $150.

Packing & shipping charges in the 48 states: 6" – $75; 8" – $85; 10" – $95.



5" and 6" LXD55-Series Achromatic Refractors and 8" Schmidt-Cassegrain with Autostar

8" Model SC-8: Includes the f/10 optical system of the Meade 8" LX200GPS for razor-sharp Schmidt-Cassegrain photo-visual imaging of the Moon, planets, and deep-space. All the telescope required by many amateurs for a lifetime of serious observing. **5" Model AR-5, 6" Model AR-6:** Excellent optical performance from the classical 2-element achromat design, with images rich in resolution and contrast and a minimum of chromatic aberration. Models SC-8, AR-5, and AR-6 allow for the full range of Autostar functions described above.

SPECIFICATIONS: Models SC-8 Schmidt-Cassegrain and AR-5 and AR-6 Achromatic Refractors — Each complete telescope includes 8" f/10 Schmidt-Cassegrain with MgF_2/standard coatings or 5" f/9 or 6" f/8 achromatic refractor with EMC super multi-coatings; quick-attach cradle ring assembly with locks; 8 x 50mm viewfinder; Series 4000 Super Plössl 26mm eyepiece; diagonal prism. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); operating instructions.

8" Model SC-8 Schmidt-Cassegrain	**$1195**
UHTC group for Model SC-8	$175
5" Model AR-5 Achromatic Refractor	**695**
6" Model AR-6 Achromatic Refractor	**895**

Packing & shipping charges in the 48 states: 8" – $85; 5" – $85; 6" – $95.

Model SN-6EC
6" Schmidt-Newtonian with Electronic Controller
Model SN-8EC
8" Schmidt-Newtonian with Electronic Controller
Model AR-5EC
5" Achromatic Refractor with Electronic Controller

6" and 8" LXD55-Series Schmidt-Newtonians and 5" Achromatic Refractor with Electronic Controller

All the performance and features of the Autostar models above, but with 4-speed (2x, 8x, 32x, 4.5°/sec.) dual-axis Electronic Controller in place of Autostar. Upgrade to the Autostar Controller, available separately, at any time.

SPECIFICATIONS: Models SN-6EC, SN-8EC, and AR-5EC — Identical in every detail to the respective Models SN-6, SN-8, and AR-5, above, but with Electronic Controller (EC) in place of Autostar Hand Controller. Electronic Controller includes four dual-axis slewing speeds: 2x for photoguiding; 8x for image centering in the main telescope; 32x for image centering in the viewfinder; 4.5°/second for rapid-slew of the telescope across the sky; plus automatic sidereal-rate RA tracking. ***#497 Autostar Controller may be added at any time in the future and permits the full range of Autostar functions, including automatic GO TO, as described for Autostar-equipped telescopes, above.***

6" Model SN-6EC Schmidt-Newtonian	**$579**
8" Model SN-8EC Schmidt-Newtonian	**699**
5" Model AR-5EC Achromatic Refractor	**579**
#497 Autostar Controller, for any EC-model above	**149**

Ultra-High Transmission Coatings (UHTC) group: 6" Model SN-6EC – $85; 8" Model SN-8EC – $125.

Packing & shipping charges in the 48 states: 6" SN-6EC – $75; 8" SN-8EC – $85; 5" AR-5EC – $85. All prices shown in this ad are suggested U.S. national mail-order retail prices. © 2003

MEADE®

RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or studying tenuous nebulosity in deep-space, Meade SP's deliver unmatched contrast and image sharpness. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP: 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each: **$79.95** (4.54)
32mm (52°); **40mm** (44°)	each: **99.95** (5.26)
56mm (52°; 2")	**199.95** (7.02)

Series 4000™ Ultra Wide Angle
84° field; multi-coated

The ultimate eyepieces: extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels.

$16.95 (2.73)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces.

$49.95 (5.26)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. (Not for LX200GPS models.)

$149.95 (7.48)

#1205 Electric Focuser: For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

New! 2" Diagonal Mirrors with UHTC

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes UHTC-coated (95%+ reflectivity) precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$119.95** (6.85)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

Series 4000™
2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle
67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 3000™ Plössls
50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm $79.95** (3.86)

#911B
#911N
#908B
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade 60-layer interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

Vibration Isolation Pads

Designed by Meade engineers, these isolation pads reduce typical telescope-tripod vibration damping times to *less than one second.* A tremendous aid for both visual and photographic astronomy. Place one pad under each tripod leg. #895 Vibration Isolation Pads, per set of three:

$49.95 (6.85)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator.

$79.95 (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95, **1.25": $29.95** (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with any brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

MEADE
MEADE

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XTE, ST-7, or AP1, or smaller; or visual observing with 1.25" eyepieces.
$149.95 (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XTE, or ST-4 through ST-10; or AP2, AP7; or for visual applications with 1.25" or 2" eyepieces.
249.95 (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.)
15.00 (3.86)

#644

#647

MEADE
FLIP-MIRROR SYSTEM

#1209 Zero Image-Shift Microfocuser

Identical to the Microfocuser supplied with Meade LX200GPS telescopes, but provided with a separate hand-box for use with all other Meade SCT models (e.g., LX10, LX50, LX90, LX200) or for Schmidt-Cassegrains of other brands. Threads directly to the telescope's rear cell. Permits extremely precise focusing of the image during visual or photographic applications; during CCD applications maintains precise image centration on even the smallest CCD chips. Operates at four speeds, from extremely slow to fast; accepts both 2" and 1.25" eyepiece barrels. Requires 8 x AAA (user-supplied) batteries.

$249.95 (9.85)

Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $99!

Epoch 2000sk *(upper display at left):* Use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** Dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely! Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software: Enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet.

EPOCH 2000sk Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM for Windows 95, 98, 2000, NT, and XP	**$99**
LX200 Interface Cable: for Meade LX200/LX200GPS operation by Epoch 2000sk.	**25**
EPOCH 2000ip Image Processing Software: On CD-ROM for Windows 95, 98, 2000, NT, and XP	**99**

f/3.3 CCD FOCAL REDUCER

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture.

$149.95 (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

MEADE
PLÖSSL
CCD FRAMING

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models; ST-4 through ST-8; AP1, AP2; and others. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above)*. Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25".

$129.95 (4.54)

#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing.

$49.95 (4.26)

#64 T-Adapter for ETX®

Threads to photo port of all ETX-90, ETX-105, and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera.

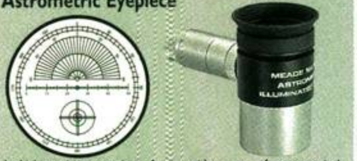
$34.95 (3.86)

#932 45° Erecting Prism for ETX®

For terrestrial observing with any ETX-90, ETX-105, or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics.

$49.95 (3.86)

MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25".

$119.95 (4.26)

Series 4000™ 8mm – 24mm Zoom Eyepiece

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25".

$219.95 (6.38)

ETX® Hard Carrying Cases

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, optional eyepieces, erecting prism, table tripod, hand controller, etc. Includes steel latches & key.

#774 Case for ETX-90 models:
99.95 (8.58)

#776 Case for ETX-105EC:
99.95 (8.58)

#775 for ETX-125EC:
149.95 (13.38)

Dew Shields for ETX®

Threads into the front-lens cell and effectively inhibits the formation of dew on the lens surface.

#670 for ETX-60/70	**19.95**
#673 for ETX-90	**24.95**
#675 for ETX-105	**27.95**
#678 for ETX-125	**29.95**

Pictor 216XT CCD Autoguider/Imager

The most advanced Autoguider/Imager in its price class. For many, all the CCD imager required for a wide range of lunar, planetary, or deep-space applications. Includes the same "point-and-shoot" simplicity of larger Pictor models. Produces smooth, natural 16-bit images of all celestial subjects. Also a precision autoguider during astrophotgraphy.

$695. (12.00)

Advanced Field Tripod for ETX-125

#887: Yields rock-solid stability for sensitive applications of the ETX-125, even at high magnifications. **Includes fixed-height tripod convenient for standing observations, equatorial wedge with alignment controls in azimuth and latitude angle, and #889 Tripod Adapter for ETX-125.** Permits either altazimuth or equatorial orientation of the telescope for astronomical or terrestrial observing. Tripod legs are 2"-diameter chromed steel. For field use the tripod collapses for easy transport.

$349.95 (14.00)

#889 Adapter: Available separately, permits attachment of ETX-125 to any Meade LX10 or LX200 Field Tripod or wedge. **$69.95** (7.70)

ETX® Deluxe Field Tripod

#884: Constructed of strong, lightweight steel; designed specifically for ETX-90, ETX-105, and ETX-125 Astro Telescopes. Tripod height adjusts from 25" to 43", for seated or standing observations. Graduated scale for elevation angle from 20° to 90° permits precise polar alignment of the telescope for astronomical applications. Tripod tilts and locks at 90° for terrestrial applications or for altazimuth use with Autostar. Telescope attaches to tripod in seconds with 2 thumbscrews. **Includes custom-fitted carry bag *(shown)* with pocket for accessories.**

$199.95 (10.00)

#771 Aluminum Carrying Case

High-quality, lightweight aluminum, suitable for storage of eyepieces, camera adapters, filters, etc. Fully foam-lined. 15" x 10" x 5".

$49.95 (5.78)

Electric Focusers for ETX®

Meade-engineered for smooth, rapid focusing with ETX-90, -105, or -125. Four-speed operation from coarse to microfine. Standard-equipment hand controller accepts one 9v. (user-supplied) battery and focuses all ETX telescopes. Or focus through the telescope's Electronic Controller (EC) or through Autostar.

#1244 Electric Focuser for all ETX-90 and ETX-105 models: **$119.95** (6.85)

#1247 Electric Focuser for ETX-125 models: **$119.95** (6.85)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

ANACORTES TELESCOPE, Anacortes, WA.
Orders & Information: 800-850-2001.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 847-367-4600.

WOODLAND HILLS CAMERA & TELESCOPE, Woodland Hills, CA. Orders: 888-427-8766; Info.: 818-347-2270.

EFSTONSCIENCE, Toronto, Ontario, Canada
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario, Canada
Orders & Information: 416-783-4140.

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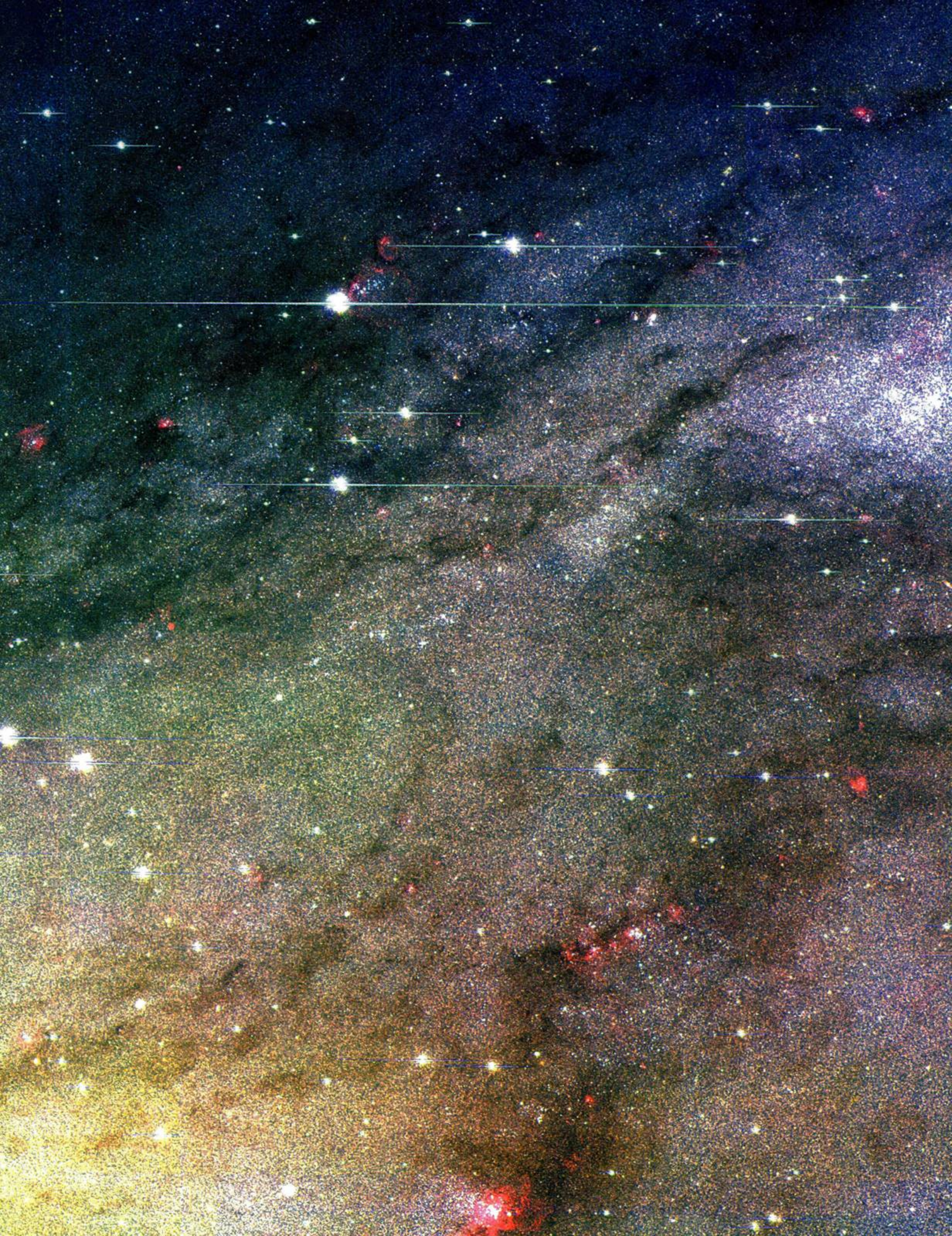
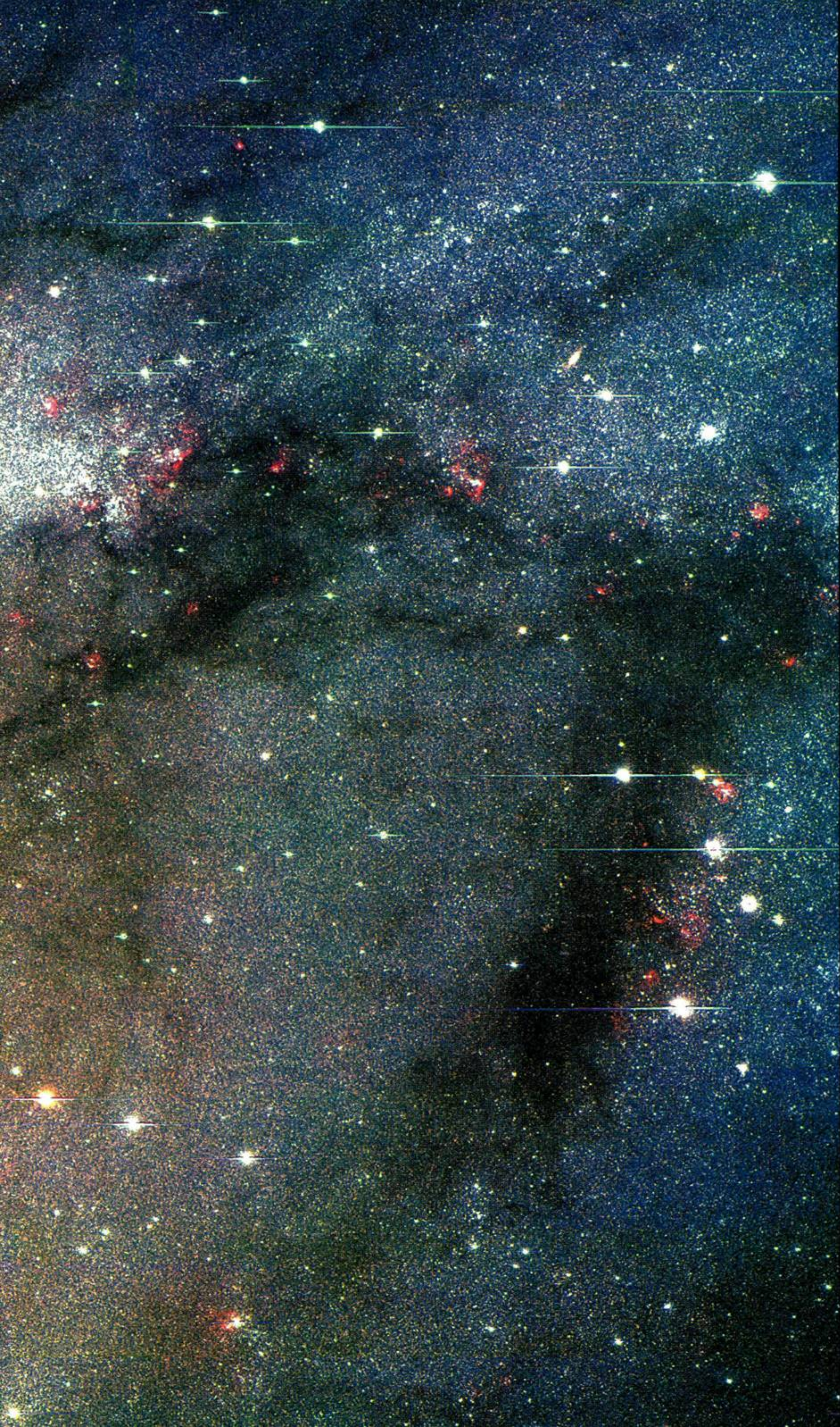




sky Gem

Andromeda's Starry Realm

Distinct stars, clusters, and nebulae pepper the Andromeda Galaxy (M31) in this image taken with the 8-meter Subaru Telescope on Mauna Kea. The image shows part of the galaxy's southwestern region, composing less than 5 percent of M31. The change in star colors, from yellow at lower left to blue at upper right, reflects the galaxy's history of star formation. The yellow stars lie closer to M31's center and are billions of years old, while the blue stars are much younger and hotter.

Subaru Telescope/NAOJ

Anyone can sell you a telescope.

Authorized Meade Dealer

Meade ETX-90EC **$495** ($545 w/UHTC)
Meade ETX-105EC **$695** ($770 w/UHTC)
Meade ETX-125EC **$895** ($990 w/UHTC)

#497 Autostar **$149**

Hardly a day goes by that we don't get a note or e-mail message like the one reprinted on the next page, or a call that goes something like this: "Your ads are right. Dealer so and so advertises low prices – but they don't have what I want in stock, they couldn't answer *any* of my questions, and they wanted my credit card number before they'd even *talk* to me. They said if I wanted to ask questions, I should call the manufacturer . . . and then they hung up on me!"

If you want the right telescope, you need more than a camera store clerk armed with only a price list and a puzzled look when you ask questions.

What you *really* need are people who take the time to listen to what *you* need, people who answer your questions truthfully, people with years of experience using and selling telescopes who can help you get the most telescope for your dollar. That's exactly who you'll find at ***astronomics*** – people with a combined total of 160 years of experience using and selling telescopes!

Unlike camera stores and shopping mall gift shops, telescopes are our specialty at ***astronomics****,* not just a sideline. We're a family-owned full-line telescope dealer – not just a few toy telescopes stuck off in the corner of some no-help department store, toy store, or gift shop as an afterthought. And, unlike department store clerks, we don't work on commission, so we won't try to sell you more than you need just to pad our paychecks.

We've been helping people choose the right telescope since 1979. We have the experience to help *you* pick the scope that fits your needs . . . *and your budget* . . . from the hundreds of Celestron, Discovery, Meade, Questar, Stellarvue, Takahashi, TeleVue, TMB, and Vixen scopes we stock. And with our large inventory, we can usually ship you the right scope right away.

astronomics. No hard sell. No guesswork. Just honest advice, the *right* scope, and a good price. Call us at (405) 364-0858 and find out for yourself.

"Optics as good as I have seen . . . in any telescope . . . at any price."

A review in June's *Sky & Telescope* said the **TMB 100** 4" f/8 ED triplet apochromatic refractor had "optics as good as I have seen in any refractor, indeed in any telescope I've tested or used at any price." It just confirms what dozens of our very satisfied customers have been saying about their TMB apo refractors for months.

Not only do the TMB ED apo refractors have optically unsurpassed triplet optics and precision mechanics (such as a 3" focuser), but many of the sizes listed below are available from stock. Even those that may be temporarily out of stock are usually available again in few short months, not a few years, as is the case with another well-known brand.

Why wait years for another triplet apo when you can be observing with the best right now? For more details and pictures, visit our website to see the apo refractors that are the talk of experienced astronomers everywhere.

TMB 80/6	80mm (3.1") f/6	\$1690^{00}
TMB 80/7	80mm (3.1") f/7	1690^{00}
TMB 100	100mm (4") f/8	3290^{00}
TMB 105	105mm (4.1") f/6.2	3290^{00}
TMB 152	152mm (6") f/7.9	6990^{00}
TMB 175	175mm (7") f/8	11,990^{00}
TMB 203	203mm (8") f/9	19,990^{00}
TMB 254	254mm (10") f/9	39,995^{00}

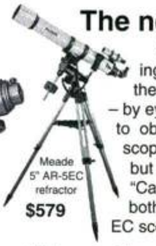
Custom-built Dobs.

Astronomics offers custom-made truss tube Dobsonians hand-crafted by Pete Kron, a long-time Astronomics customer who is now a full-time member of our staff. Pete has been custom-building Dobs for over 15 years, in sizes up to a 36" f/5, and is known for using premium quality components. While Pete specializes in 18" through 24" apertures, custom mirror sizes and focal ratios are also available. He can also upgrade your bulky and unwieldy commercially-made Sonotube Dobsonian to an easily transportable truss tube version.

Prices start at $3500 for a custom-built 18" scope. Converting your commercially-made Sonotube Dob optics to a truss tube mount starts at $1500 for a 16" f/4.5 scope.

For more information, or to discuss specific pricing, you can contact Pete via e-mail care of questions@astronomics.com. You can also reach him by phone toll-free from 9 to 5 Monday through Friday at (800) 422-7876.

The new Meade LXD55 EC scopes . . . *add go-to when you need to.*


Meade 5" AR-5EC refractor **$579**

Some observers enjoy hunting for celestial objects the way the pioneering astronomers did – by eye, star hopping from object to object. Others want a go-to scope to do the hunting for them, but have a budget that says, "Can't afford a go-to yet." For both groups, the Meade LXD55 EC scopes are the answer!

The 5" EC multicoated achromatic refractor and fast focal ratio Schmidt-Newtonian 6" and 8" reflectors (with either standard or optional UHTC optics) are complete working scopes, with standard dual-axis DC drives and a four-speed/four direction EC hand control (which are costly options with competitive scopes). You can star hop or use setting circles to find objects. Once found, the scopes track those objects automatically while you observe.

For the purist or the observer on a budget, they're all the scope you need. *But . . .* if you add an optional Autostar computer later, you'll have a fully computerized go-to telescope with 30,000 stars and objects in its memory. You can have as much or as little automation as you want, at a price you can afford *now!*

$729 Meade 8" SN-8EC f/4 reflector ($854 w/UHTC)

Want the latest TeleVue telescope or eyepiece? We have it in stock.

Whether it's the newest telescope or the newest eyepiece (like the 3mm to 6mm Nagler zoom at $380), if it's from TeleVue, chances are good we have it in stock. Gibraltar, Panoramic, and TelePod mounts; Nagler, Radian, Panoptic, and Plössl eyepieces; Powermates and Barlows; Everbrite diagonals; and more – we have it all. Others say they carry TeleVue, *but we actually keep it stock.* Call us and see.

All packages come without a mount, but with an eyepiece, star diagonal, tube ring for mounting, and case. Basic optical tubes, without accessories, are also available.

NP-101 **$3595**

TV-85 **$2080**

NP-101, package, without mount	\$3595^{00}
TV-102, package, without mount	2635^{00}
TV-102, optical tube only	2200^{00}
TV-85, package, without mount	2080^{00}
TV-85, optical tube only	1680^{00}
TV-76, package, without mount	1675^{00}
TV-76, optical tube only	1275^{00}
Pronto, package, without mount	1120^{00}
Pronto, optical tube only	775^{00}

Vixen. European best-sellers. Now in the U. S.

For many years, the high quality of Vixen telescopes and optical accessories from Japan has made them best-sellers in Europe. Now, that same high Vixen mechanical and optical quality is also available in the U. S. – imported by TeleVue, a company with a sterling reputation for quality of its own.

Whether it's a telescope, a German equatorial mount, or a visual or photographic accessory, if it's from Vixen, the chances are good it's in our inventory. We have all the Vixen Lanthanum long eye relief and wide angle long eye relief eyepieces ready to ship. Also in stock are the well-known and standard-setting Great Polaris and Great Polaris DX mounts to use with your own optics. If you want optics that are out of the ordinary, we have Vixen's ED glass, fluorite, and dual ED doublet apochromatic refractor optical tubes and complete telescopes. If it's a Vixen, it's probably in our stock right now. Check our website for a complete listing of available items or call us and see for yourself.

Vixen

$2200

Vixen GP ED102S 4" f/9 ED apochromatic refractor (shown with optional motor drive)

The best CCD book. Period.

Before you spend $3000 on a CCD camera, spend $49.95 on this book. It will be $49.95 well spent.

Ron Wodaski's book **The New CCD Astronomy** is simply the best and most complete reference available about CCD imaging for the beginning to advanced CCD astrophotographer. It includes everything you need to become proficient at CCD imaging, including a free subscription to on-line updates and reference materials. This is the only CCD reference book you'll ever need to buy. *Period.*

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Our 4 brands of light pollution filters bring dark skies to a light-polluted world.

If city lights are blocking your view of the heavens, get rid of the light pollution with one of the many light pollution filters we stock.

We carry **Celestron** broadband filters in both 1.25" eyepiece and Schmidt-Cassegrain rear cell versions.

We carry **Meade** broadband, narrowband, and Oxygen III filters in 1.25" eyepiece versions and in rear cell versions for Schmidt-Cassegrain use.

We carry **Sirius** 1.25" and 2" broadband light pollution filters, nebula and planetary contrast enhancement filters for eyepiece use; their variable filter system; and their IR and UV photo filters.

We carry the **Thousand Oaks** broadband, narrowband, Oxygen III, and H-Beta filters in both 1.25" and 2" versions for eyepiece use.

Our free catalog helps you pick the right Celestron, Meade, Questar, Stellarvue, Takahashi, TeleVue, TMB, or Vixen scope.

For detailed information on individual products, visit our Web site. You can call us at (405) 364-0858, or e-mail us, for your *free* copy of our catalog AST. It covers all the scopes and accessories we stock – from Bushnell, Canon, Celestron, Coronado, Discovery Telescopes, JMI, Losmandy, Meade, Nikon, Parallax Instruments, Pentax, Questar, Rigel Systems, SBIG, Software Bisque, Stellarvue, Takahashi, TeleVue, TMB, Vixen, and more. We'll include our guide on how to pick the right scope and your discount prices on the 1000+ products we carry. (Sorry, U. S. sales only.) The catalog is yours for only the cost of a one minute phone call. The information we send will make it the most useful minute you'll ever invest in astronomy.

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Why wait? We'll ship your Meade LX90 from stock.

Meade 8" LX90

$1695

Meade prices are about the same anywhere you call. So why order a Meade scope or accessory from a dealer who charges your credit card, then makes you wait and wait until he finally gets around to ordering what you want? Not when you can usually get the Meade scope you want from stock . . . right now . . . at the right price . . . right here at ***astronomics.***

Meade's LX90 Schmidt-Cassegrain will let you enjoy 8" go-to astronomy for not a lot of money. An LX90 with standard optical coatings is only $1695. The UHTC (Ultra High Transmission Coatings) version of the LX90 (with up to 20% brighter images) is only $1870. Both have a heavy-duty adjustable height tripod, an Autostar go-to computer with a built-in 30,223 star and object data base, a big 8 x 50mm finder, and a 26mm Super Plössl eyepiece.

We usually have the LX90 in inventory at all times (both the standard and UHTC optics versions), so the chances are good you can get *your* LX90 with little or no delay. If Meade is shipping the LX90 *(or any Meade scope)* for a dealer to keep in stock, the chances are very good that we *have* it in stock.

7" to 10" Meade GPS UHTC scopes ship from stock. They do all the work so you can see 20% more.

Meade 8" LX200 GPS with UHTC

$2670

Meade LX200GPS telescopes have all the features you've dreamed about since you started astronomy – plus optional UHTC (Ultra High Transmission Coatings) optics that give you up to 20% higher light transmission so you can see 20% more of the Universe.

Meade's *fully automatic* GPS (Global Positioning Satellite) alignment system, with its true north and true level sensors and automatic magnetic declination correction, takes the time and guesswork out of setting up your scope. You'll be observing in mere minutes. The built-in computer, with a database of over 145,000 stars and objects, will find objects for you *automatically*. You'll spend more of your time looking *at* heavenly bodies and less time looking *for* them.

Meade GPS scopes with UHTC optics let you see up to 20% more, and give you more time to see it, too. We keep 7", 8" and 10" LX200GPS scopes in stock. Chances are good we have one in stock for you.

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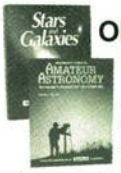

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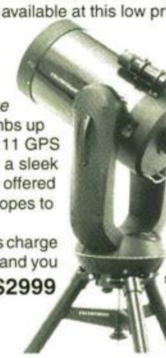
A \$450 bino for $\$179^{95}$!

One couple liked the $450 list **Celestron Tasco 8 x 42mm Rare Bird** roof prism binoculars they bought from us so much that they bought seven more to give to their grown kids and their spouses!

Free $7.95 lens cleaning pen with purchase

Armored, waterproof, multicoated, with BaK4 prisms, a soft case, wide neck strap, 6.6° field, and long 16mm eye relief. The Rare Bird is great for astronomy, birdwatching, sporting events, or just all-around family fun. We started with 400, but we're down to less than 100 still available at this low price.

The NexStar 11 got a rave review. You can have yours next week!



NexStar 11 GPS

Celestron's 11" go-to GPS scope – the **NexStar 11 GPS** – got a *rave* review in *Sky & Telescope*. The review gave it "an enthusiastic two thumbs up and a gold star." They said it has "brains and good looks. The NexStar 11 GPS puts Celestron's time-tested 11-inch f/10 Schmidt-Cassegrain optics in a sleek new package that includes some of the most advanced electronics ever offered in a mass-produced telescope . . . Celestron is the first to take Go To scopes to the next step in their evolution, and it's a nice step indeed."

Multicoated optics are standard with the NexStar 11 GPS (other brands charge extra). We have the NexStar 11 in stock (34 as this was written). Call us and you can be observing with yours in about a week.

$2999

Multicoated optics are free on the NexStar 8 GPS.

NexStar 8 GPS

$2499

The in-stock 8" Celestron **NexStar 8 GPS** (28 on hand as this was written) has Starbright high transmission multicoated optics for brighter images at no extra cost. And you can easily convert its unique Fastar optics to a blazingly fast f/1.9 focal ratio for wide field CCD imaging.

With an optional Fastar lens assembly and a $1295 SBIG ST-237A CCD camera, the NexStar 8 GPS will record a huge 32 x 42 arc minute field. That's larger than the full Moon and more than three times the sky area imaged by a $7695 camera on other 8" scopes without Fastar!

Of all the computerized GPS scopes, *only the NexStars have multicoated Fastar optics at no extra cost!*

A 5" GPS-ready scope for only $899!

NexStar 5i

$899

shown with optional photography accessories, tripod, and computer

The **Celestron NexStar 5i** is the first 5" telescope to have a fully automatic GPS go-to computer available as an option. No other 5" telescope has a GPS system! Even better, the modular nature of the NexStar 5i means that you can build up to a fully automatic GPS system gradually, starting at only $899 for a complete working tabletop scope and adding computer, GPS, etc., as wanted. And multicoated optics are standard equipment with the NexStar 5i, not an extra-cost option as with other brands. NASA uses 5" Celestron multicoated optics on the Space Shuttle. Don't your eyes deserve the same premium images?

Eyepiece storage cases from $\$2^{49}$.

Bolt-type containers protect eyepieces dew and dust. Foam inserts cradle eyepieces to protect them from accidents. Our website at **www.astronomics.com** lists which eyepieces fit into which containers (including other containers not listed below).

42mm x 60mm holds most Celestron NexStar, Meade Series 3000, and TeleVue Plössls. .... **$\$2^{49}$**
52mm x 80mm Holds TeleVue Radians, Nagler 6, most Barlows, large Celestron Ultimas, etc. .... **$\$3^{49}$**
65mm x 80mm Holds most illuminated reticles, 22mm Panoptic, 12mm Nagler, etc. .... **$\$3^{99}$**

> Looking forward to future orders from Astronomics for more goodies. You're obviously a customer service oriented company. Again, many thanks.
>
> **Customer Quote of the Month #131**

The new Celestron Modular i Series 8" GPS SCT starts at only $1199!

NexStar 8i

$1199

shown with optional tripod and computer

CELESTRON

If you compare prices and specs, you'll see that the **Celestron NexStar 8i** go-to costs less than other comparably-equipped 8" scopes. Starting at only $1199 for a complete working tabletop scope (not even available from the competition), you can add the options that you, and your budget, feel comfortable with. An *iCOMP* computer hand control with a 40,000 deep space object memory is $149. A light weight tripod is $149. A heavy duty tripod (same as the NexStar 11 GPS) is $299. If you want the convenience of GPS auto-alignment, add it for only $199. However you outfit your NexStar 8i, it's enough scope to keep you happily observing the rest of your life, at prices that leave competitive scopes behind.

A whole lot less shaking going on!

"Truly a quantum leap in binocular observing . . ." is what *Sky & Telescope* said about handholding Canon image-stabilized binoculars. Their images are rock-solid, not jittery, no matter how unsteady your hands. You'll see more detail than conventional binos. There are big 15 x 50mm and 18 x 50mm models excellent for astronomy. Full details are on our website.

Canon

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Discovery Dobs are not cheap . . . just inexpensive.

8" f/6 DHQ

$449

Why settle for an imported Dob when you can have made-in-the-USA quality *for less money!* Discovery doesn't use inexpensive, imported, mass-produced optics that are only spot-checked to see if they're acceptable. Discovery optics are made in California by optical craftsmen, one quality mirror at a time. Each is hand figured to diffraction-limited performance, and it doesn't leave the Discovery optical shop until it's right.

Each DHQ series Dob has an adjustable metal primary mirror cell, a true *thin vane* adjustable 4-vane diagonal mirror spider, *two* Plössl eyepieces, a built-in tube balancing system, a tube carry handle, new oversized bearings, a 6 x 30mm finder, and a dust cover. For only $49 more, you can get an upgrade kit that adds two more Plössl eyepieces, an eyepiece rack, a second dust cover, and a Moon filter!

Premium Dobs are also available in 10" to 17.5" apertures. And for those who need portability, easy set-up and take-down truss-tube Dobs are available in apertures of 12" to 24". Here are the 6" to 10" Discovery DHQ Dob prices:

6" f/5 Discovery DHQ	**$\$339^{00}$**, plus $49 freight
6" f/8 Discovery DHQ	**$\$339^{00}$**, plus $49 freight
8" f/6 Discovery DHQ	**$\$449^{00}$**, plus $49 freight
8" f/7 Discovery DHQ	**$\$449^{00}$**, plus $49 freight
10" f/4.5 Discovery DHQ	**$\$649^{00}$**, plus $69 freight
10" f/5.6 Discovery DHQ	**$\$649^{00}$**, plus $69 freight

The Stellarvue refractor is a "hot new product."

AT1010A **$\$499^{95}$**

shown w/optional diagonal and eyepiece

The 80mm f/6 **Stellarvue AT1010** achromatic refractor was named a "Hot New Product" in the December 2001 issue of *Sky & Telescope*. Even better, independent reviews say it competes favorably with ED semi-apochromatic scopes that cost twice its modest price, and that it easily outperforms imported achromatic scopes in color correction and resolution. The AT1010A has triple tested hand-assembled optics, tube rings, a tripod adapter, a 2" focuser with 1.25" adapter and T-threads, red dot finder, oversize rubberized focus knobs for easier use in cold weather, and a soft padded carry case. It's a super deal and it's in stock to ship now. It's one of several Stellarvue refractors we keep in stock, in apertures from 78mm to 102mm, *including APOs*.

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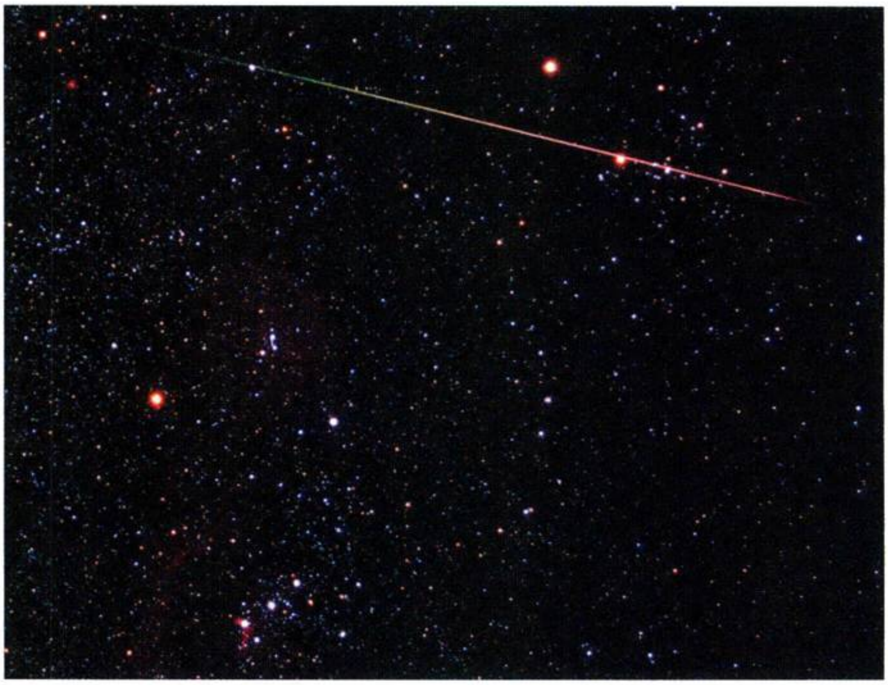
Sounds of Meteors?

I was surprised to read in the August 2002 issue that it may be possible to hear meteors as they streak across the sky (Strange Universe). I had that experience about ten years ago while watching the Geminids. Every time a meteor appeared, I thought I heard a "hissing" noise. I didn't think that was possible, so I more or less dismissed it. I told a few people, but no one believed it, so I thought no more of it. Since reading Bob Berman's comments, however, I now feel that it really was possible. The weather must have been just right, as well as my receptivity to the radio noise. I watch the Geminids every year, and I don't believe I have heard anything since. But it is my favorite meteor shower because of that incident. Thanks for a great article. — *Mark Swaim, Winston-Salem, North Carolina*



If conditions are just right, you just might be able to hear a meteor as it soars overhead, such as this one, captured during the 2001 Leonid shower. Gianni Tumino and Melania Pluchinotta

October Extravaganza

I felt the October 2002 issue of *Astronomy* was one of the best ever. The detailed article on Mercury ("Heading Back to the Forgotten Planet") was very interesting, as it is a planet that gets too little attention. I found "An Astronomer Reads Archaeology's Message" fascinating, while the photo of the Eagle Nebula on page 12 and the star cloud photos in "Capturing Jewels of the Milky Way" were incredible. Keep up the great work! — *David Allen Hines, Kingston, Pennsylvania*

Strange But True

In "The Man Who Fell to Earth" (Strange Universe, November 2002), Bob Berman writes that "Earth merely follows a straight path through curved space-time. And, because the Sun has warped the space here in its vicinity, our planet merely plummets along the shortest, straightest, laziest route (called a geodesic) in this curved matrix." This is a common misconception. Only light rays follow geodesics. Space-time curvature in the Sun's vicinity is traced out by the very slight bending of light rays from distant stars that happen to pass close to the Sun (the effect discovered in 1919 by Arthur Eddington during a total solar eclipse), not by the orbital motions of the planets. Instead, Earth is in a constant free-fall in the Sun's gravity field, just as the Moon or the space shuttle is in free-fall in the gravity field of Earth. These motions have nothing to do with curved space-time. — *Govert Schilling, author of* Flash! The Hunt for the Biggest Explosions in the Universe

Molecular Structures

I was very interested to learn more about the complex organic chemistry going on in space, along with the analytical challenges these studies involve ("It Came From Outer Space," November 2002). But as an organic chemist, I noticed a few minor problems with the molecular structures illustrated. For example, glucose is shown as having one too many carbon atoms, while glycerol has an extra hydrogen atom attached to the middle carbon. Additionally, in a few of the structures, some hydrogen atoms that should be attached to the carbons are not shown. This is shorthand commonly used by chemists, but may not be clear to everyone. — *Chuck McFarland, Cleveland Heights, Ohio*

Correction

The graph on page 38 of the December 2002 issue was labeled incorrectly. The horizontal axis should have read "Frequency" instead of "Wavelength." — Astronomy *editors*

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SCT OTA and CGE Computerized Mount — Portability and Stability In A Complete System. All CGE's can be quickly disassembled into easy to handle transportable components — even the CGE 1400! Recognized for superior stability, German Equatorial mounts eliminate the tuning fork like vibration associated with fork mounted telescopes. The new CGE's are ideal for viewing objects in every part of the sky – even in the North where fork mounts have difficulty pointing.

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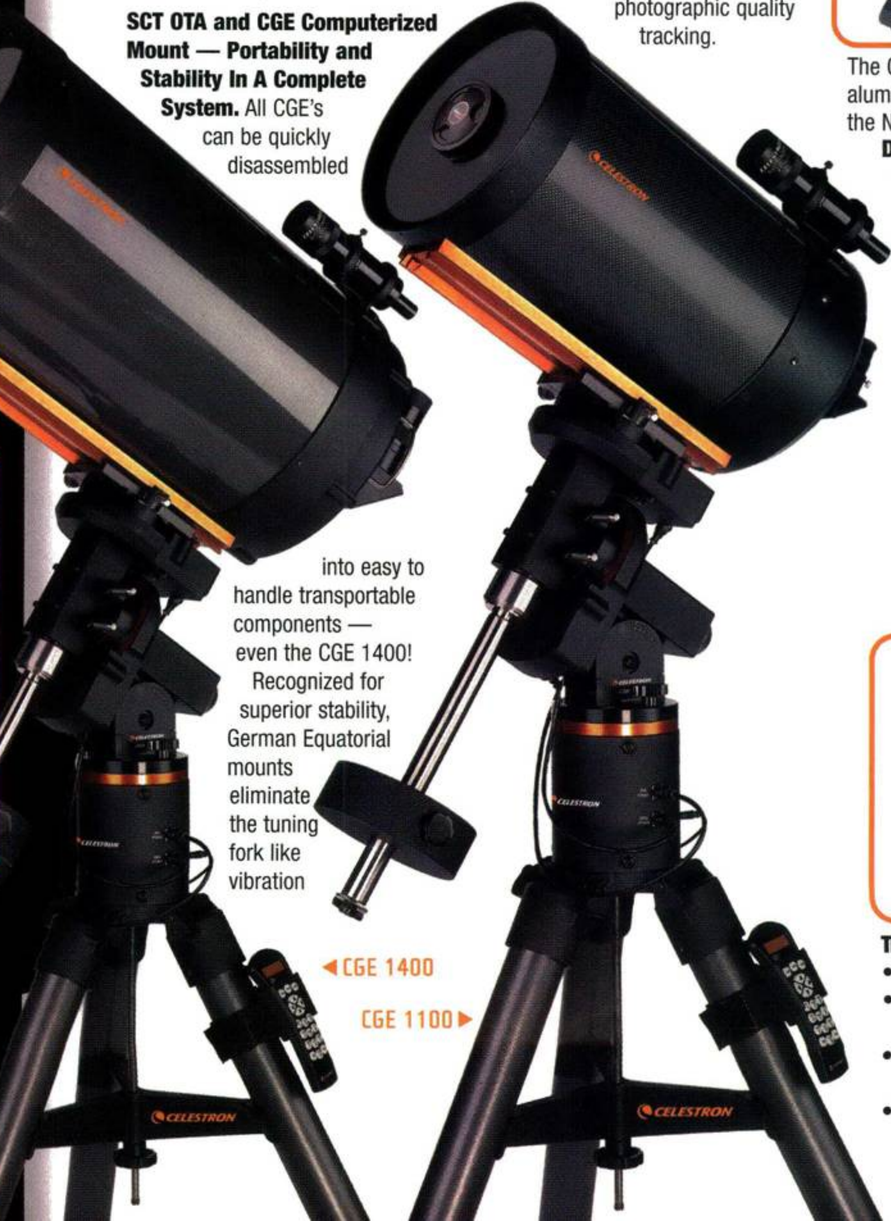

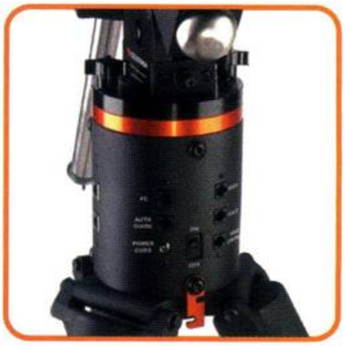

The CGE Mount is made of CNC machined aluminum and stainless steel and features the NexStar® control system.

Drive Base Features:

- Autoguide port
- PC port
- 3 Accessory Ports
- Real time clock – maintains time even when powered down
- Strain relief power cord cable protection
- Backlit power switch

Drive System:

- U.S. manufactured Pittman 12V DC servo motors
- U.S. manufactured Berg bronze drive gear mated with stainless steel worm shafts
- 4 point RA clutch system for no slip pointing precision

Tripod Features:

- Dual Leg Support
- Center leg brace provides outward preload
- *Lower leg brace provides* inward preload
- Extendable powder-coated carbon steel legs

OPTICS	CGE 800	CGE 925	CGE 1100	CGE 1400
Focal length	2032mm; f/10	2350mm; f/10	2800mm; f/10	3910mm; f/11
Secondary Obstruction	2.7"	3.35"	3.75"	4.5"
Resolution (Rayleigh)	.68 arcseconds	.59 arcseconds	.50 arcseconds	.39 arcseconds
Coatings	StarBright®	StarBright®	StarBright®	StarBright®
Optical Tube	Carbon Fiber	Aluminum	Carbon Fiber	Aluminum
Fastar Compatible	Yes; f/1.95	No	Yes; f/2	Yes; f/2.1

STD. ACCESSORIES	CGE 800	CGE 925	CGE 1100	CGE 1400
Eyepiece	25mm Plössl	25mm Plössl	40mm Plössl	2" 40mm Barrel
Star Diagonal	Prism Diagonal	Prism Diagonal	Prism Diagonal	2" Mirror Diag. with $1^{1/4}$" Adapter
Finderscope	6x30	6x30	9x50	9x50
Power Supply	Car Battery Adapter	Car Battery Adapter	Car Battery Adapter	Car Battery Adapter
Counter Weights	1-11lb.	1-25lb.	1-25lb.	2-25lb.

PRICING

CGE Computerized Mount (#91524):
$2999 + $95 Shipping & Handling
CGE 800 (#11058):
$3499 + $105 Shipping & Handling
CGE 925 (#11059):
$3799 + $145 Shipping & Handling
CGE 1100 (#11061):
$4149 + $245 Shipping & Handling
CGE 1400 (#11063):
$5799 + $295 Shipping & Handling

Optional Accessories:

- 12V DC Rechargeable Power Supply (#18774)
- 2"-70° Apparent Field, Axiom Eyepieces
- Reducer Corrector; f/6.3 (#94175)
- CN16 GPS Accessory (#93963)

Specifications

Software

40,000 + Objects
400 User defined objects
Hibernate – Maintains alignment even while powered down
Polar alignment routines for Northern and Southern hemisphere
Filter limits – Displays only objects above the horizon
Permanent programmable PEC – Corrects periodic tracking errors inherent in all worm drives
Smooth ramping of slew motors to reduce wear on drive train

Electronics

Home sensors on RA and Dec axes
Real time clock
Fail safe slew limit switches in RA
12V DC Servo Motors with integrated optical encoders, 256CPR used in quadrature
Encoder resolution: .11 arcseconds

Mechanics

CNC machined aluminum and stainless steel components

RA axis

- 1" solid ground stainless steel shaft
- Two Preloaded .9835" I.D. x 2.047" O.D. tapered roller bearing
- One 4.724" O.D. x 3.543" I.D. thrust bearing
- 180 tooth, 5.625" diameter enveloping bronze gear preloaded to maintain gear mesh while clutch tension varies, manufactured to AGMA 10 quality.
- .4375" diameter precision 303 stainless steel worm, manufactured to AGMA 10 quality
- 4 point RA clutch system pre-loading a 4.65" stainless steel disk for no-slip drive and pointing precision

Declination axis

- 1" solid ground stainless steel shaft
- Two Pre-loaded .9835" I.D. x 2.047" O.D. tapered roller bearings
- One 3.250" O.D. x 2.500" I.D. thrust bearing
- 180 tooth, 5.625" diameter non-enveloping bronze gear preloaded to maintain gear mesh while clutch tension varies, manufactured to AGMA 10 quality.
- .4375" diameter precision 303 stainless steel worm, manufactured to AGMA 10 quality
- 2 point Dec clutch system pre-loading a 4.65" stainless steel disk for no-slip drive and pointing precision

Latitude Range: 10° to 60°
CGE Maximum Payload: 65 lbs.

Tripod

- Tripod height: 36" to 50"
- Leg material: cold rolled carbon steel
- Upper leg diameter: 2.75"
- Lower leg diameter: 2.375"

CELESTRON
CGE 800 ▸
CGE 925 ▸

Pittman 12V DC servo motors; Berg bronze drive gears are mated with stainless steel worm shafts for smooth operation.

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"We ran through the alignment procedure during evening twilight and observed throughout the entire night without missing a beat...and every object that we commanded the scope to point at ended up in the field of a low-power eyepiece."
"The optics in the NexStar loaned to us were some of the finest I can recall in a Schmidt-Cassegrain, but if anything the optics in the scope we purchased at random were even better."
–Dennis di Cicco
"The NexStar 11 GPS: Beauty and Brains"
Sky and Telescope
February 2002

A telescope that combines the design features, engineering, performance, and value of the NexStar® 11GPS doesn't come out of the *Blue*.

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CELESTRON

NexStar® 11GPS
$2999*
+ $125 Shipping & Handling
Includes Standard Heavy-Duty Adjustable Tripod

At Celestron, we know that the whole is greater than the sum of all of its parts. That's why we design, engineer, and manufacture the NexStar 11GPS telescope from the beginning with features and performance that add up to a whole lot more telescope than the competitor's 8", 10" and 12" GPS telescopes — ***and a better value.***

Here's why: Compare the design features and construction of the NexStar 11GPS (as well as the NexStar 8GPS) to the competitor's 12", 10", and 8" GPS telescopes. Every component of the NexStar 11GPS, from its rugged integrated drive base and fork arm design to the unique carbon fiber optical tube assembly has been designed specifically for this model NexStar telescope. Only Celestron matches and meticulously hand-figures each individual telescope optical system.

Understanding Resolution.

Do coatings affect resolution? No! When comparing telescopes, it's extremely important to clearly understand the relationship between coatings and resolution. ***Fact: Resolution is a function of aperture. Coatings only affect light transmission.*** It is a function of aperture or diameter of the objective lens. Rayleigh's Criterion defines resolution as: $\theta=1.22*\lambda/D$, where λ is the wavelength of light, D is the diameter of the objective lens, and θ is the resolution in radians. Image brightness is a function of aperture, focal ratio, and system's light transmission efficiency. ***StarBright® coatings have been standard on all of our Schmidt-Cassegrain telescopes since 1983 AT NO ADDITIONAL COST.*** For primary and secondary mirrors, StarBright coating is a precise multilayer application of Al, SiO_2, TiO_2, and then another layer of SiO_2 — all to maximize reflectivity. On the corrector lens we apply precise layers of MgF_2 to both surfaces to maximize transmission.

The dark-adapted (scotopic) eye's peak sensitivity is at 510nm. The sensitivity drops off dramatically on either side of 510nm. In fact, as the wavelength approaches 400nm, the eye's sensitivity goes to almost 0%. The same is true as the wavelength goes to 600nm. Celestron's StarBright® Coatings are designed to peak at 510nm, the peak sensitivity of the scotopic eye. Celestron offers these coatings at no additional cost to the consumer. The chart below shows the transmission at 510nm for both Celestron and competitor's large aperture SCT telescopes.

Transmission at 510nm for all Celestron large aperture SCT's and competitor's SCT's

NexStar 8"	87%	No Additional Cost
NexStar 9.25", 11", 14"	85%	No Additional Cost
Competitor's Standard Coatings - all SCT's	77%	No Additional Cost
Competitor's UHTC	86%	**Cost: $175 (8"), $235 (10"), $295 (12")**

Competitive information obtained from December, 2002 issue of *Sky and Telescope*.

NexStar 11GPS. Quality from the inside out.

Carbon Fiber Tube — Strong and lightweight with 1/4 of the thermal expansion of an aluminum tube. Scratch and dent resistant.

Optical Tube Assembly Outer Rails — An outer rail on each side of the optical tube provides rigid, flex-free movement. Mounting tolerance allows cell to contract and expand.

NexStar quality and reliability. Designed in. Not added on.

COMPARISON OF DESIGN FEATURES

This chart compares the significant design and engineering features of the NexStar 11GPS with competitor's 10" and 12" GPS telescopes.*

Feature/Specification	**NexStar 11GPS**	**Competitor's 10"**	**Competitor's 12"**
Mirror Coatings	StarBright®; 5-step multilayer	Standard; (Enhanced Coatings $235)	Standard; (Enhanced Coatings $295)
Fork Arm	Dual fork tine cast aluminum with integrated hand control receptacle. Fork arms are long enough to permit optical tube to swing through	Dual fork tine cast aluminum; hand control attaches to fork arm with external bracket.	Dual fork tine cast aluminum; hand control attaches to fork arm with external bracket; fork arms not long enough to allow optical tube to swing through
Leveling Technique	Internal switch - levels the tube to the mount to the accuracy of 1 arcminute; Usable for both Alt/Az and equatorial	Ground level switch; only useful for Alt/Az	Ground level switch; only useful for Alt/Az
Cord Management	Internal slip ring design. Power is mounted to non-rotating part of drive base. Accessory ports rotate with top of drive base	Requires internal hard stops to avoid tangling and disconnecting wires; accessory ports do not rotate with telescope which can cause cords tangling	Requires internal hard stops to avoid tangling and disconnecting wires; accessory ports do not rotate with telescope which can cause cords tangling
Carrying Handles	Ergonomically designed for ease of lifting	Attached to front of fork arms	Attached to front and back of fork arms
Motors	Pittman mfg. in U.S.A.;12V DC Servo; quiet	Unknown; very noisy	Unknown; very noisy
Gears	Berg mfg. in U.S.A.; 5.625" precision bronze gears on both axes; 180-tooth; mated with stainless steel worm shaft	5.75" aluminum gears on both axes	5.75" aluminum gears on both axes
Bearings	9.5" roller azimuth bearing	4" dia. polar bearings	4" dia. polar bearings
Focusing Mechanism	Two (2) preloaded ball bearings	Bushing and washer	Bushing and washer
Optical Tube	Carbon Fiber; reduces thermal expansion; 4x less than aluminum	Aluminum	Aluminum
Fastar Compatible	Yes	No	No
Weight of Telescope	63 lbs.	62 lbs	75 lbs
GoTo Precision	1.5 arcminutes	2 arcminutes	2 arcminutes
Boot-up Time	1-1.5 sec.	20-25 sec.	20-25 sec.
GPS Alignment Time	2.5 min.	More than 4.5 min.	More than 4.5 min.
Quick Align	Yes	No	No
Database Filter Limits	Automatic filter limits for named objects list	No database filter limits for custom object lists	No database filter limits for custom object lists
Price**	**$2,999 + $125 S&H = $3,124**	**$2,495 + $145 S&H + $235 for Enhanced coatings = $2,875**	**$2,995 + $215 S&H + $295 for Enhanced coatings = $3,505**

How you can tell wrong from right.

Celestron strongly believes that the only way to design and manufacture our NexStar GPS telescopes is the ***right way***. The right way means understanding what expectations our customers have when they make an investment in our products, and designing and manufacturing telescopes that meet or exceed their expectations. That means paying attention to details and not cutting corners. Compare the following examples of why we believe that we have designed the NexStar 8GPS and 11GPS the right way and what we believe is wrong with the design of the competitor's GPS telescopes. Consult the chart to the left for an additional comparison.

Their Way:

- The competitor's GPS antenna is partially obstructed by the finderscope.
- When the base rotates, cables can easily wrap around the fork arms and become entangled.
- Carrying handles are poorly designed and located making it difficult to lift the telescope.
- Boot-up time can take as much as 20-25 sec.
- Hand control displays objects below the horizon.
- Motors and gearbox are noisy.
- The competitor's 10", and 12" drive base is undersized.
- The OTA (Optical Tube Assembly) on the competitor's 12" will not swing through and clear the drive base; the fork arms have spacers to attach to the base.
- The complete optical system is not hand-figured.
- The hand control is attached to a bracket with the cable hanging loose.
- Enhanced optical coatings cost extra
- Focus mechanism uses bushings intead of ball bearings.

Our Way:

- Celestron's GPS antenna is not obstructed by the finderscope.
- Celestron's drive base design eliminates any potential for cord/cable wrap.
- Carrying handles are integrated into fork arms to make lifting and transporting easier.
- Boot-up and alignment are fast and easy.
- Hand control has many advanced features and is user-friendly; only shows objects above the horizon.
- High quality precision gearing ensures quiet, precise operation.
- Large diameter drive base and bearing track provides maximum stability. Especially important when equatorially mounted.
- Carbon fiber tube minimizes thermal expansion/contraction; important for astrophotography or CCD imaging.
- Mirror shift minimized through use of precision bearings.

* Version Tested: 1.0b Telescope Serial #01039 All comparative information obtained from User Manual for this model.

**Prices obtained from December, 2002 issue of *Sky & Telescope*
Set-up Information: Starting Position: Alt.= -90 and Az =0
Date: 09.18.02 Time: 8:00 PM (no daylight savings) Long: 118 West Lat: 34 North

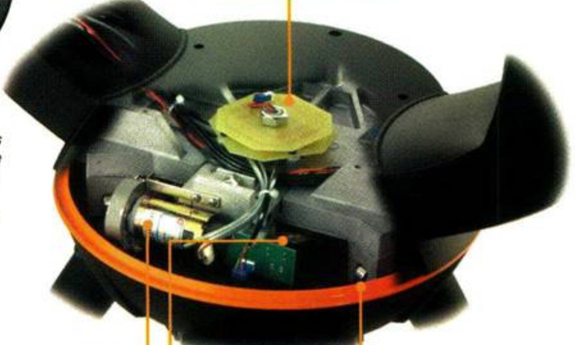
***16-channel GPS* — Interference free. Finderscope is positioned away from GPS antenna. Pinpoints your exact location on Earth with an unobstructed view.**

***Upgraded hand control and software features* — 40,000 object database; new features include compass calibration, polar alignment routine, EQ AutoAlign, database filter limits, hibernate, Auto north and level, wedge align algorithm, Quick Align, user-defined slew limits.**

***Electronic compass* — Finds true North when used in conjunction with NexStar software.**

***Ergonomically designed fork arm with integral handles* — Integrated handles in fork arms designed for ease of carrying and safe and easy setup and transportation.**

***Auxiliary Ports* — The NexStar's auxiliary ports are located on the top of the base which rotates as the telescope turns preventing accessory cables from wrapping around fork arms.**



***Internal Slip Ring* — The NexStar's power cables will never wrap and telescope accessory cables will not get wrapped around the telescope.**

***Bearing and shaft* — Heavy-duty preloaded tapered roller bearing on both axes.**

***Worm shaft* — Stainless steel worm shaft has .4375 pitch diameter and is preloaded with two ball bearings. The worm is made from a single piece of steel to minimize run-out, which is the source of periodic error.**

***Heavy-duty aluminum spring loaded worm block* — On both axes; minimizes backlash.**

***Motor board* — Each axis is controlled by its own 8-bit microcontroller.**

***Drive Motors* — Made in the U.S.A., Pittman Lo-Cog™ brush commutated DC motors offer smooth, quiet operation and long life. The motor armatures are skewed to minimize cogging which is required for low speed tracking. Windings are resin impregnated for greater reliability in incremental motion application.**

***Precision bronze gear* — 32 pitch, 5.625" pitch diameter, 180-tooth bronze gear. Manufactured in the U.S.A. by W.M. Berg, Inc. Manufactured to AGMA Quality Class 10 standard which minimizes total composite error and backlash.**

***Unique roller bearing design* — Base rotates around a wide 9.5" track for maximum stability; especially important when equatorially mounting for imaging.**

To take a virtual tour of the NexStar 11GPS or to locate your nearest Authorized Celestron Dealer, please visit us at www.celestron.com

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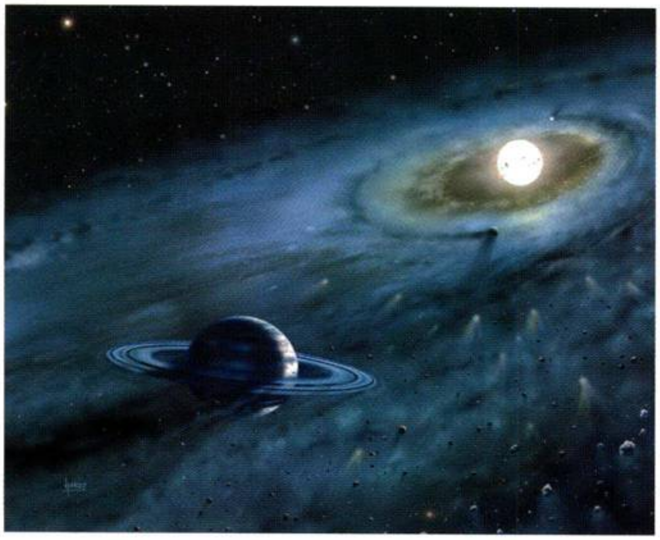
EXTRASOLAR PLANETS

Planets Pop Up in Unusual Places



This artist's concept shows what Fomalhaut's planetary system might look like. While inner planets sweep up dust in a vast disk, a Saturn-sized planet creates a wake through the dust. David Hardy

▶ It seems hardly a month goes by without some major discovery changing the way we view planets in our galaxy. In October, however, astronomers doubled the fun, announcing new planets in two unique places — one lurking inside a dusty disk surrounding a star, the other circling one member of a tight binary star system.

An international team of researchers led by Wayne Holland of the United Kingdom Astronomy Technology Centre (UKATC) in Edinburgh has found a huge, distorted disk of cold dust surrounding the 1st-magnitude star Fomalhaut. "We were amazed to find that the disk is bent about the star," says Holland. "This strongly suggests there is an orbiting giant planet shaping the dust we see."

The disk covers an area about the size of the Sun's Kuiper Belt of comets, which extends beyond the orbit of Pluto. It looks a little like a doughnut with a hole in the center, with the ends of the doughnut appearing a little brighter.

"Our models of the disk suggest that a planet similar in mass to Saturn is creating a wake or trail of dust," says team member Mark Wyatt of the UKATC. "The gravity of the planet creates points near its orbit called 'resonances' where comets get trapped. When two comets collide, they release a shower of dust that we see as a bright spot in the disk."

The disk is so cold that it hardly emits any light — so little that even Hubble can't see it. Instead, the researchers studied the disk's submillimeter radiation, which has wavelengths between infrared and radio waves. They used a special camera called SCUBA, whose detectors are cooled to 0.1° Celsius above absolute zero, attached to the 15-meter James Clerk Maxwell Telescope on Mauna Kea.

Astronomers with the McDonald Observatory Planet Search confirmed a planet in the 3rd-magnitude binary star system Gamma Cephei. Artie Hatzes of Thüringer Landessternwarte Tautenburg in Germany, Bill Cochran of the University of Texas – Austin, and their colleagues found the planet orbiting the system's larger star, which has a mass 1.59 times that of the Sun. The planet itself weighs 1.76 Jupiters and orbits 2 astronomical units from the star, a little farther than Mars's distance from the Sun. It takes 2.5 years to complete one orbit. The second, smaller star lies about as far away from the primary as Uranus does from the Sun.

Although astronomers have found planets orbiting stars in binary systems before, the stars in those systems were a hundred times farther apart than those in Gamma Cephei, says Cochran. "The stars were far enough apart that they were essentially acting independently."

The discovery will help theorists better understand how planets form in binary systems. But more importantly, it implies that there may be more planets in the galaxy than previously thought, because unlike the Sun, the majority of stars in the Milky Way belong to binary or multiple star systems. — Richard Talcott

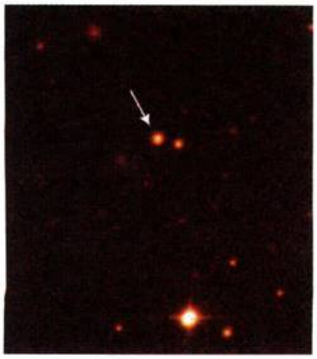
POPULATION III STARS?

A Star without Heavy Elements

▶ Sixty years ago, the late German-American astronomer Walter Baade divvied up the Milky Way's stellar inhabitants into two basic groups. He designated relatively young stars rotating in the plane of our galaxy as "Population I," and the much older stars belonging to the galaxy's halo and collection of globular clusters as "Population II." The Population II stars also have a relatively low abundance of elements heavier than helium — what astronomers refer to as metals.

Astronomers have long speculated about the nature of these stars' ancestors, which would have formed soon after the Big Bang and contained no metals, only hydrogen and helium. Most believed that direct evidence of such a Population III was out of their reach.

The star HE 0107–5240 (arrow) contains fewer heavy elements than any star previously observed.



STScI/DSS

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Purchase a NexStar® 5i or 8i by January 31, 2003 and receive a FREE computerized hand control and tripod!

A $300 VALUE.

There's never been a better opportunity than right now to take your astronomical viewing to the next level. Celestron's affordable NexStar 5i and NexStar 8i are exciting new additions to our renowned NexStar family of computerized GoTo telescopes that includes the NexStar 8GPS and 11GPS. NexStar 5i and NexStar 8i take the best of our coveted NexStar 5 and 8 to the next level of performance and operating features. These new GoTo's include all of Celestron's newest hardware and software enhancements in an affordable and expandable system. Most important, these two new NexStar GoTo's will fully align when used with the new optional CN16 GPS accessory, and you can put the power of our newest software features and expanded object database to work with the computerized hand control. Best of all, the computerized hand control and sturdy tripod are yours FREE if you purchase your telescope by January 31, 2003.

New Hardware Features:

Two Ports Conveniently Located On The Drive Base:

- **AutoGuide Port** — Easy connection of AutoGuider for astrophotography.
- **Auxiliary Port** — Use for smart accessories like the **optional CN16GPS accessory**.

New Software Features:

- **Compass Calibration** — Allows you to point to true north more accurately, by compensating for magnetic north offset and local anomalies.
- **Polar Alignment Routine** — Facilitates polar alignment for CCD imaging or conventional 35mm astrophotography.
- **EQ AutoAlign** — Now the patented AutoAlign is available even when the telescope is mounted on a wedge.
- **Database Filter Limits** — Now available in Equatorial mode as well as Alt/Az.

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Computerized Hand Control & Tripod—
A $300 VALUE

*Suggested mail order retail price.
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Offer effective 11/04/02-01/31/03

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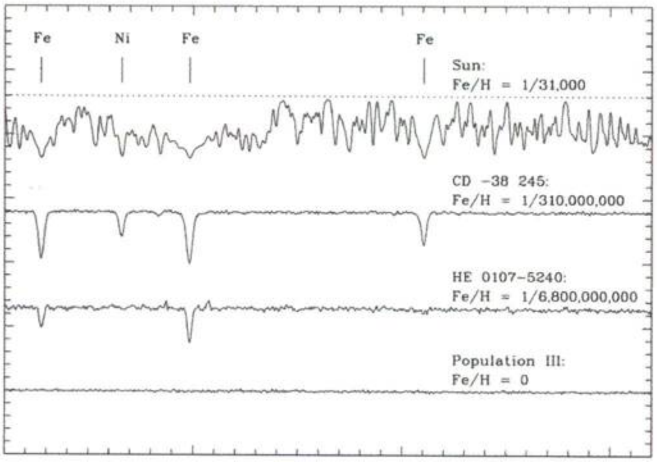
Optional GPS Accessory:

CN1GPS Accessory
93963 Mounts to both the NexStar 5i and 8i. Converts the telescope to GPS align for automatic alignment without manually entering any data. — **$199**



A small part of the visible spectrum demonstrates the uniqueness of HE 0107–5240. The top spectrum shows the Sun, which has 1 iron atom for every 31,000 hydrogen atoms. Next is the star CD –38 245, the previous record holder for fewest heavy elements with 1 iron atom for every 310 million hydrogen atoms. HE 0107–5240 has only 1 iron atom for every 6.8 billion hydrogen atoms. A hypothetical Population III star (bottom) has only hydrogen, helium, and a little lithium. ESO

Conventional theory dictates that Population III stars would have ranged anywhere from 100 to 1,000 times the mass of the Sun — a Population I star — and as a result lived short lives, ending their tenure as some of the galaxy's earliest supernovae. But now, an international team of astronomers believes it may be on the verge of actually detecting these long-sought-after progenitors.

Such hope stems mainly from recent high-resolution spectra of the red-giant star HE 0107–5240, which confirms it as the most metal-poor star ever detected. It has a "metallicity" of only 1/200,000 of the Sun and tips the scale at just 80 percent of the Sun's mass. With the discovery of this 13-billion-year-old relic and perhaps others like it within their sights, astronomers from the ongoing, decade-old Hamburg/ESO (European Southern Observatory) survey now realize that long-lived, low-mass, Population III stars could still be lurking in the outermost regions of the galaxy's halo.

Most of the Population III stars presumably ended their lives as supernovae, seeding the young Milky Way with its first batch of heavy elements — cooked up in the nuclear furnaces at the stars' cores. But some of these Population III stars may still be around today, simply because their low mass demands that they take a very long time to burn their fuel.

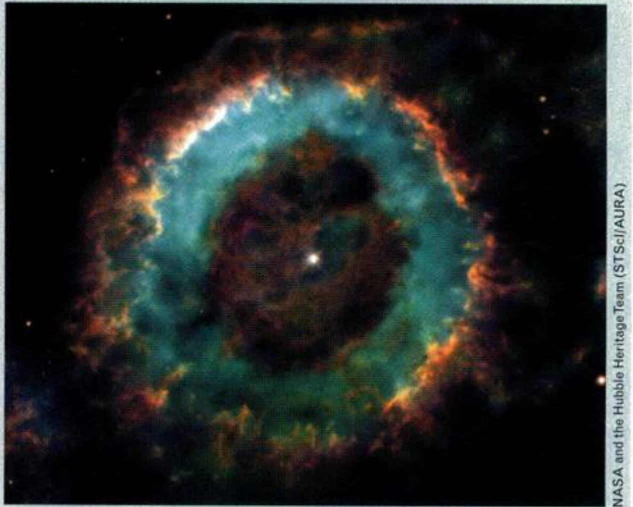
"If you take one supernova and let it explode into a globular cluster-sized ball of gas, that supernova would release enough metals to take the cluster all the way from zero to 1/300 of the Sun's metal abundance," says survey team member Timothy Beers of Michigan State University. "HE 0107–5240 formed out of this incredibly dilute mixture. So we know there's just not a lot of time between where we are with this star and the last step backward to the Population III stars. This demonstrates that the chances of finding an unpolluted Population III star are excellent."

HE 0107–5240 lies in the constellation Phoenix, some 36,000 light-years from Earth in the high latitudes of the southern galactic halo. As a 16th-magnitude star, it is some 10,000 times fainter than the faintest stars visible to the naked eye. But with help from the new Ultraviolet-Visual Echelle Spectrograph on ESO's 8.2-meter Very Large Telescope in Chile, its low metal count could be observed at high resolution. The astronomers reported their research in the October 31 issue of *Nature*.

The team now stands only a quarter of the way through its observing roster of some 8,000 stars, so be prepared for more surprises. As Beers puts it: "The farther into the outer halo you go, the greater the likelihood of finding lower metallicity stars. So, we're going down to 17th magnitude, or out to about 100,000 light-years."

— Bruce Dorminey

HUBBLE SPACE TELESCOPE


NASA and the Hubble Heritage Team (STScI/AURA)

WHEN A STAR GIVES UP THE GHOST, it often blossoms into a more lively-looking object. That's certainly true of planetary nebula NGC 6369, affectionately known to backyard astronomers as the Little Ghost Nebula because it appears as a small, ghostly cloud. Planetary nebulae form when a star with roughly the Sun's mass nears the end of its life. After swelling to a red giant, the star ultimately ejects its outer layers, leaving behind a hot stellar core and an expanding cloud of gas. Energetic ultraviolet radiation from the remnant star ionizes the gas and causes it to glow. In this Hubble image of the Little Ghost, the prominent blue-green ring measures nearly 1 light-year across and glows with the light of ionized hydrogen and doubly ionized oxygen. The ultraviolet radiation grows less intense farther out, giving rise to the reddish glow. NGC 6369 lies in Ophiuchus at a distance between 2,000 and 5,000 light-years.

Smaller Cost. Bigger Value!

Now the NexStar® 4GT is an even better value. New lower price, improved features, and portability make this high performance GoTo telescope a must-have!

Featuring high-quality Maksutov-Cassegrain optics, the NexStar 4GT is an ideal telescope for observing and photographing the wonders of space. Incredible light-gathering and a wide field of view gives you views 189% brighter than a 60mm refractor. Sturdy metal construction provides an extremely stable observation platform making observing at higher magnification much easier.

Computerized capabilities like Auto Align, automatic Tour Function, easy-to-use hand control and 4,000+ object database all help make the NexStar 4GT a superstar telescope at a super affordable cost. The NexStar 4GT's deluxe features combine with Celestron's uncompromising optical standards to give amateur astronomers one of the most sophisticated and easy to use telescopes available on the market today.

NexStar® 4GT

$499*

+ $40 Shipping & Handling

NexStar 4GT shown on optional tripod (Tripod #93497- $149)

Improved Features Include:

- **Two-star alignment** — Allows you to do a two-star alignment just like other NexStar GoTo telescopes.
- **Quick-Align** — Allows the telescope to align itself without being aimed at two alignment stars.Works the same as the NX 8GPS and 11 GPS.
- **Filter Limits** — Displays only those objects within the set altitude filter limits. Works the same as NX 8GPS and 11GPS except the hand control displays a warning if there are no objects within the set filter limits.
- **Slew Limits** — Sets the limit that the telescope can slew in altitude. Will display a warning if you try to slew outside of your slew limits. Works the same as the NX 8GPS and 11GPS.
- **RS-232 Compatible** — Allows the telescope to communicate with a computer. Works with popular astronomy software such as "The Sky" or "Starry Night".

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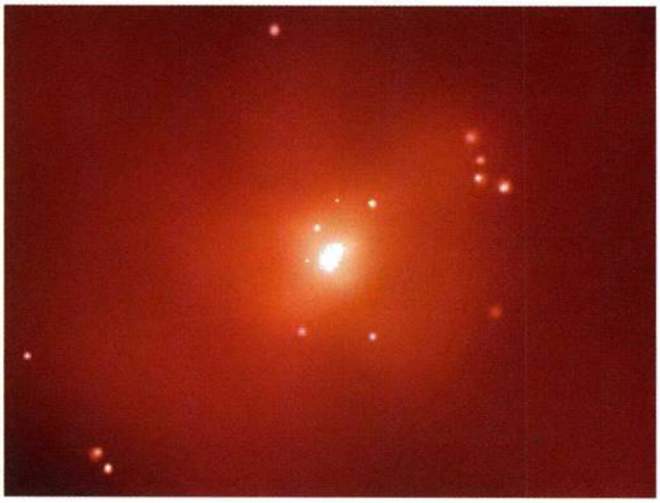
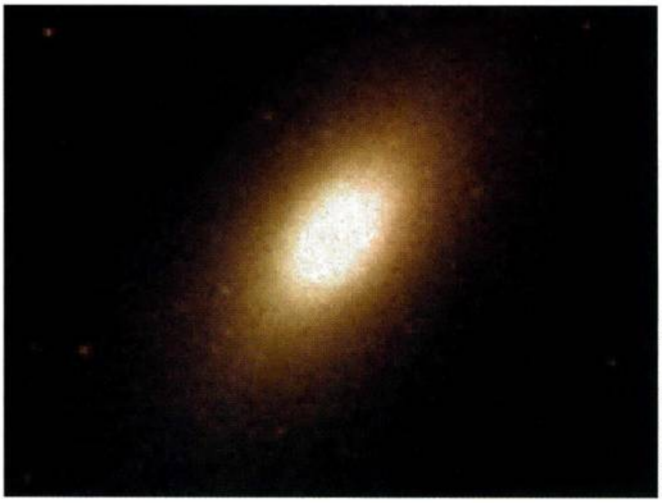


NASA/CXC/UCI/D. Buote et al.



DSS U.K. Schmidt image/STScI

An x-ray image of the galaxy NGC 720 (left) shows it has a slightly flattened cloud of hot gas oriented differently from that of an optical image of the galaxy (right). The flattening is too great to be explained by theories in which stars and gas contain most of the galaxy's mass.

X-RAY ASTRONOMY

Dark Matter Passes Test

▶ Astronomy provides a home for lots of strange concepts, and dark matter ranks among the oddest. For decades now, astronomers have observed the universe and seen less matter than they think exists. Clusters of galaxies seem to hold together for billions of years, even though their individual galaxies seem to zip around too fast to stick around. And isolated galaxies rotate as if they had massive halos surrounding them, despite any other visual evidence that there's matter out there.

A few theorists speculated that perhaps gravity doesn't behave the way everyone thinks. Most astronomers, however, looked at gravity's nearly unblemished record spanning more than three centuries and deduced that the universe contains lots of matter that can't be seen. Now new observations from the Chandra X-ray Observatory challenge the leading alternative theory, which would have eliminated the need for dark matter.

A team of astronomers headed by David Buote of the University of California – Irvine used Chandra to observe the elliptical galaxy NGC 720 in Cetus. The researchers found a slightly flattened, ellipsoidal cloud of hot gas enveloping the galaxy and oriented differently from the way the galaxy appears in visible light. The flattening is too large to be explained by theories that assume all the mass of the galaxy is contained in its stars and gas.

"The shape and orientation of the hot gas cloud require it to be confined by an egg-shaped dark matter halo," says Buote. "This means that dark matter is not just an illusion due to a shortcoming of the standard theory of gravity — it is real." The team reported their results in the September 20 issue of *The Astrophysical Journal*.

According to the standard theory, the x-ray cloud needs an additional source of gravity — a halo of dark matter five to ten times more massive than the galaxy's stars — to keep the hot gas from dissipating. If the dark matter tracked the optical light from the stars, the hot cloud would appear rounder. Its flattened shape requires a flattened halo of dark matter.

In 1983, Mordecai Milgrom of the Weizmann Institute in Israel proposed an alternative theory: Modified Newtonian Dynamics, or MOND. It does away with the need for dark matter by modifying gravity where the acceleration it produces is tiny, as it is on the outskirts of galaxies. But MOND can't explain the current Chandra observations, providing the first dynamical evidence that distinguishes between the two theories.

The Chandra observations also support the idea of cold dark matter — slowly moving particles that interact with each other and normal matter only through gravity. Other leading candidates for dark matter would produce a halo that is either too round or too flat. — R. T.

SUPERCOMPUTING

Killer Asteroids Make Big Splash

▶ Water can give life, and it can take it away. With the help of a large chunk of rock from space, water in the form of a mile-high tsunami could take life away for millions of shore-side residents. In the shadow of sensationalistic movies such as *Deep Impact* and *Armageddon*, three scientists have been quietly plugging away at creating their own realistic computer models of an asteroid hitting Earth. They find that an asteroid 0.6 mile (1 kilometer) in diameter is capable of creating tsunami waves a half-mile high that hurtle toward shore at 380 miles per hour.

Computer scientists Galen Gisler and Bob Weaver from Los Alamos's Thermonuclear Applications Group and Michael Gittings of Science Applications International Corp. created a simulation that follows the interactions between a falling asteroid and the ocean, and between the ocean and atmosphere. In their models, island-sized

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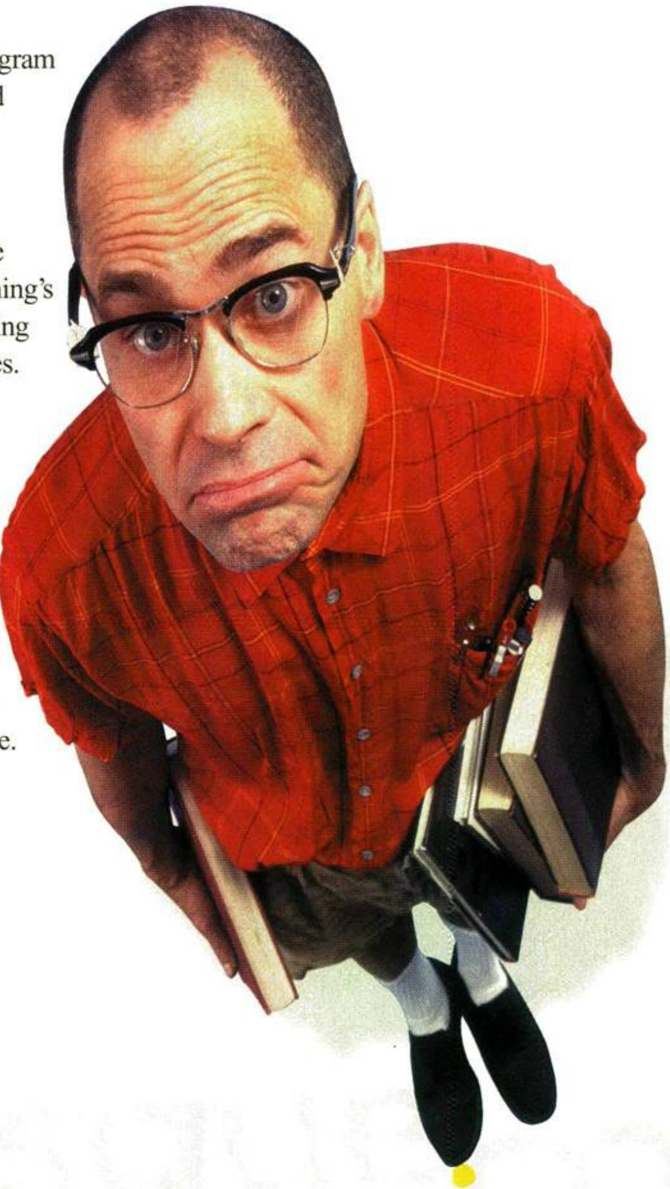

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The results of their models are nothing short of terrifying. On impact, even solid-iron asteroids vaporize quickly, as they splash jets of water more than 12 miles into the air. The water in turn falls back to the ocean and spawns tsunamis that radiate away from the aquatic crater. Initially more than 2,500 feet high, these waves abate to about 1,700 feet 40 miles from the point of impact.

To give this some perspective, consider these facts: A 30-foot-high tsunami that hit Papua New Guinea in 1998 killed 2,100 people, and 15-foot-high hurricane tides in Louisiana can travel 20 miles inland.

"We found that the one-kilometer iron asteroid struck with an impact equal to about 1.5 trillion tons of TNT," says Gisler. This is equivalent to the energy released by 1.5 million 1-megaton nuclear weapons.

Scientists think asteroid impacts killed off the dinosaurs, and ended the Cretaceous, Triassic, and Jurassic geological periods. "This is important science and has potential value in predicting and planning emergency response," adds Gisler.

Although there is only a 1 in 200,000 chance that a 1-kilometer asteroid will hit Earth in any given year, NASA is taking no chances of being caught off guard. Astronomers around the world are cataloging asteroids and their orbits, searching the skies for the big one that might not pass by. — Pamela L. Gay

IKONOS SATELLITE

Space Imaging

THE 1,000-FOOT-WIDE ALUMINUM BOWL of the Arecibo Radio Telescope stands out against the lush, hilly terrain of northern Puerto Rico. This image was taken with Space Imaging's IKONOS satellite, the first high-resolution commercial satellite. It orbits 423 miles above Earth and has imaged millions of square miles on every continent. Visit http://www.spaceimaging.com/gallery/default.htm to see an IKONOS gallery. Arecibo's triumphs include discovering the first planets outside our solar system, orbiting the pulsar B1257+12, establishing the 59-day rotation period of Mercury, and finding the first pulsar in a binary system, which helped confirm Einstein's theory of general relativity and won a Nobel Prize for Russell Hulse and Joseph Taylor.

GLOBULAR CLUSTERS

A Cluster's Mixed-up Start

▶ The mammoth globular cluster Omega Centauri stands as odd man out among its peers in the galactic halo. This unique system appears to be made of three distinct populations of stars with different compositions and orbital dynamics. This amalgamation points to a mixed stellar heritage for the Omega Centauri system.

Normally, astronomers can use globular clusters as stellar laboratories for studying large populations of stars that have identical ages and metallicities, the latter a measure of the fraction of atoms heavier than helium present in a star's atmosphere. A metal-rich star, like the Sun, is enriched with heavy elements created in previous generations of stars. Generally, the stars in globular clusters have very few metals — their compositions reflect the primordial mixture of atoms that came out of the Big Bang with a minimal enrichment from the first few supernovae that lit up the early universe.

Omega Centauri is not normal, however. First, it's the largest globular cluster belonging to the Milky Way. And while its main stellar population is metal poor, it has two secondary populations of progressively more metal-rich stars. These stars are also younger and have different orbital dynamics than the main population. The explanation for these characteristics may be that

The globular cluster Omega Centauri contains a million stars within a 150-light-year diameter. Recent studies suggest that Omega formed through two separate periods of merging with other stellar systems.

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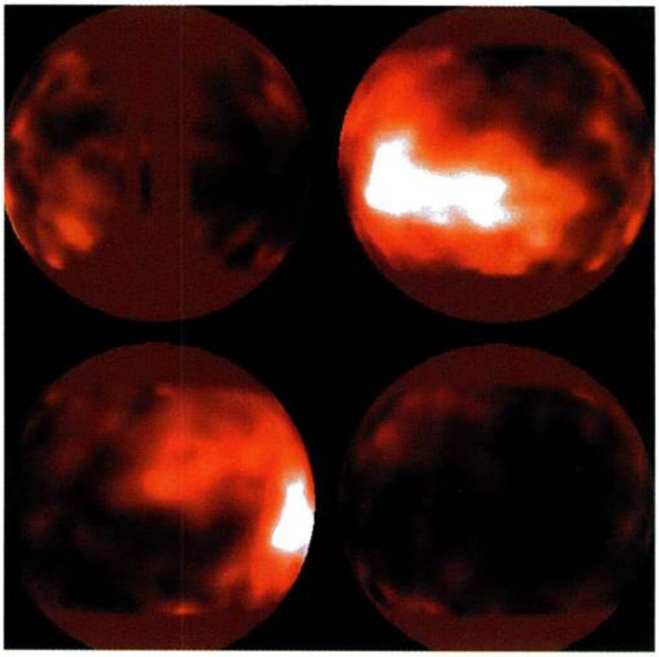
Omega is not really a globular cluster, but instead the remnant of a small galaxy that was partially disrupted by our Milky Way and, like our own galaxy, continues to consume smaller systems.

"We are witnessing the process of hierarchical merging, simultaneously occurring on two very different scales," says Francesco Ferraro of Italy's Bologna Observatory, who led a team that recently reported its results in *The Astrophysical Journal Letters*. "The Omega Centauri system is merging into the Milky Way, and its most metal-rich star system is merging into Omega Centauri."

Hierarchical clustering stands as one of the leading theories of structure formation. In this model, small structures that formed in the early universe merge to form progressively larger structures over time. This works on all scales, with small galaxies merging to form larger ones, and galaxies coming together to form galaxy clusters. Currently, the Sagittarius Dwarf galaxy is being consumed by the disk of the Milky Way.

Omega Centauri appears to have lost its gas and much of its original population during repeated orbital passages through the plane of the Milky Way. The most metal rich of its secondary populations is probably a small stellar system that once orbited Omega but lost its independent identity as it fell into the main group. The exact origins of Omega's intermediate population is still a matter of debate: It could be a population that formed while Omega was still an independent galaxy, or it may be another consumed star system. — P. L. G.



Planetary scientist Ralph Lorenz predicts that the Huygens probe will find the surface of Titan — Saturn's large, haze-shrouded moon — to be sculpted by impacts, tectonics, and erosion. The Hubble Space Telescope images seen here show only indistinct light and dark features on the moon's surface during one 16-day rotation. UA Lunar and Planetary Laboratory

SATURN'S MOONS

Sculpting Titan's Landscape

▶ Nearly 350 years after Christiaan Huygens discovered Titan, we still know little about Saturn's largest moon. A thick, oppressive atmosphere cloaks the nearly Mars-sized satellite in an orange haze and leaves scientists wondering what might lie underneath. Now one researcher is partnering science with imagination to predict what Titan might look like when the Huygens probe, a vital part of the Cassini spacecraft, descends to the moon's surface in January 2005.

Ralph Lorenz of the University of Arizona's Lunar and Planetary Laboratory expects Huygens will find dark, complex vistas sculpted by impacts, tectonics, erosion, and tidal forces. To make his predictions, Lorenz considered how much influence each type of landscaping force would have compared with their power on Earth.

Like some other planetary scientists, Lorenz suspects Titan may have lakes and small oceans of black, hydrocarbon liquids that have rained from the moon's thick, organic-rich atmosphere. Some of this dark liquid may pool in the bowls of Titan's craters, just as water floods some craters on Earth.

According to Lorenz, there should be plenty of craters to hold these imagined lakes. "I think craters will be the dominant landforms," he says. Lorenz calculated how many there might be on Titan by looking at the number of craters on other saturnian moons and taking into account Titan's greater gravity.

Titan's craters would endure longer than those on Earth because erosion wouldn't wear them away as easily as it does here. Lorenz estimates that erosional effects by phenomena such as wind-blown sand and wind-driven waves would be 400 times weaker than they are on Earth. This is because the generator of atmospheric erosion — sunlight — is much weaker on Titan.

Tectonics, another heat-dependent landscaper, could drive earthquakes and build mountains, Lorenz postulates. He assessed the strength of Titan's inner heat engine by estimating how much radioactive material exists inside the moon. He concludes that tectonic forces on Titan would be only 50 times weaker than they are here.

Titan's orbit isn't circular, so tidal effects might also play a small role on the surface, adds Lorenz. "The tidal effects depend on the mass of Saturn, the diameter of Titan, and the size and eccentricity of Titan's orbit," he explains. While tides would affect bodies of liquid on the surface, it might also help heat the moon's interior. "But this is quite a small effect," he admits.

"These considerations suggest that Titan's landscape will have bizarre complexity, with craters and tectonics featuring prominently," Lorenz concludes. "These features will be comparably much less eroded than on Earth or Mars."

Until the Huygens probe reaches Titan's surface, we'll have to wait to find out whether Lorenz's predictions parallel reality.
— Vanessa Thomas

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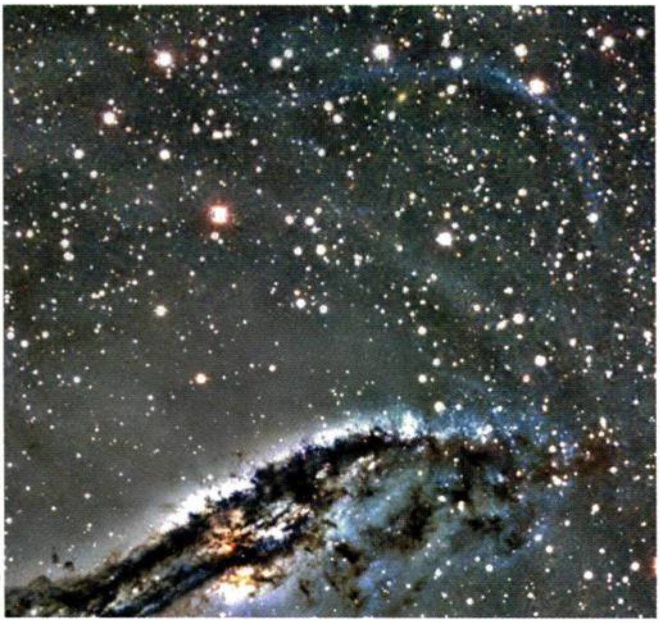

E. Peng (JHU), H. Ford (JHU/STScI), K. Freeman (ANU), R. White (STScI), NOAO/AURA/NSF

An arc of blue stars (upper right) in the nearby galaxy Centaurus A represents the remains of a dwarf galaxy it shredded a few hundred million years ago.

GALAXY EVOLUTION

Centaurus A Shreds Dwarf

▶ The practice of cannibalism among humans seems to be dying out. However, the etiquette of galaxies in the universe appears somewhat less refined. Galactic cannibalism is alive and well, and happening in our own backyard.

Astronomers studying Centaurus A (NGC 5128), a galaxy only 10 million light-years from Earth, have found an arc of blue stars at least 2,000 light-years long. The arc appears to be 200 million to 400 million years old and created when Centaurus A pulled in a satellite galaxy, ripping it apart.

"The tidal forces of the main galaxy caused a burst of star formation within the infalling galaxy," says Eric Peng of Johns Hopkins University, who led the research team. "What we see now are these young stars spread along the remnant of the incoming orbit." The astronomers reported their discovery in the December *Astronomical Journal.*

The team used the 4-meter telescope at Cerro-Tololo in Chile to create images of Centaurus A through several color filters. Comparing the images highlighted regions of different colors and revealed the young, blue stars in the arc. This allowed the researchers to identify the arc as a remnant of a merger and estimate when Centaurus A absorbed it.

"One of the joys of science is unexpected discoveries," says team member Holland Ford of Johns Hopkins. "Although our pictures were taken for another project, we were certainly excited when the blue arc popped out." — R. T.

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Cassini Eyes Saturn for First Time

NASA/JPL/SwRI

Cassini's first view of Saturn.

Looking serene and majestic, the Ringed Planet posed for the Cassini spacecraft on October 21. Cassini was still 177 million miles (285 million km) from Saturn when the camera took a series of images through several filters. Three of those images were composited to show the planet and its rings as they would appear to the human eye. The planet's semi-circular shadow reaches partway across the rings, leaving the outer A ring in sunlight. Cassini will enter orbit around Saturn on July 1, 2004, and release the Huygens probe to descend through Titan's atmosphere in January 2005.

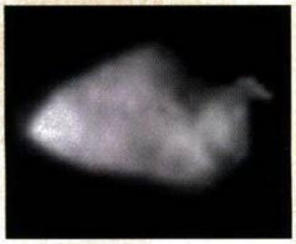
VLT Interferometer Passes Hurdle

ESO

The VLT's four scopes may soon be working together.

Astronomers this past September moved a step closer to making one of the world's great telescopes even better. Preliminary tests successfully combined light beams in pairs from the four 8.2-meter telescopes that compose the European Southern Observatory's Very Large Telescope (VLT) in Chile. Each of the massive telescopes worked together with one other telescope by sending beams of light through a complex system of optics to a common focus. When all four telescopes are eventually hooked together to make an interferometer, resulting images will have a resolution equal to a telescope with a diameter of about 660 feet (200 meters).

Stardust Looks at Asteroid Annefrank



NASA/JPL

Asteroid Annefrank proved bigger than expected.

NASA's Stardust spacecraft flew within 2,050 miles (3,300 km) of asteroid 5535 Annefrank on November 2. Images taken near the closest approach show Annefrank is about 5 miles (8 km) across, twice as big as predicted from Earth-based observations, and its surface reflects 10 to 20 percent of incoming sunlight. This flyby served as a full dress rehearsal for Stardust's encounter with Comet Wild 2 in January 2004. During that flyby, it will collect dust samples that will be returned to Earth in 2006.

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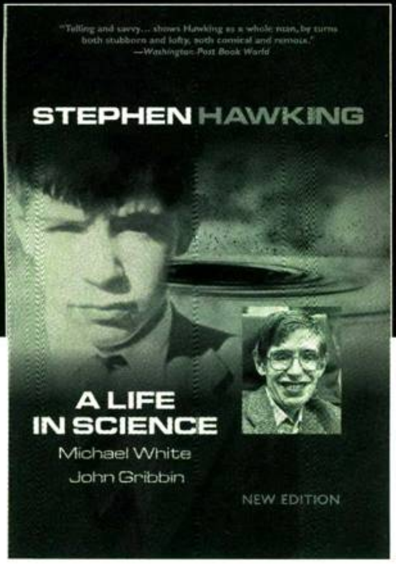
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QUA

SARS EXPLAINED

Forty years of high-energy discoveries suggest a black hole lurks at the center of nearly every galaxy.

by William Keel

Quasars have bedeviled astronomers from the moment they were discovered. They look like stars but shine from so far away scientists once doubted their grasp of cosmic expansion. Don Dixon

EVEN NOW, THE VERY WORD "QUASAR" carries a buzz. It's mysterious and exotic. No doubt that's why quasar has been used as a brand name for TV sets, software, publishing companies, consulting firms, diamond brokers — even a bicycle.

But what about the real thing? Are the objects themselves still mysterious and exotic? By now astronomers have studied them and their relatives for four decades. Has our understanding of quasars reached the maturity we associate with turning forty? Mature or not, the picture has grown much clearer — and, paradoxically, both simpler and more complex.

Since they were discovered, quasars pushed astronomy to the limit. Their spectral lines were shifted unprecedentedly far toward red wavelengths, implying that they lay at great distances. Along with their comparative brightness, this meant quasars were the most powerfully radiating objects in the universe.

For instance, the first quasar identified, the radio source 3C 273 in Virgo, lies about 2 billion light-years away. Even at that distance, it glows at 13th magnitude, within easy reach of a medium-sized backyard telescope. Given its distance and brightness, 3C 273 must be emitting several hundred times as much visible light as a galaxy like the Milky Way. And astronomers now know that, as quasars go, 3C 273 is something of an underachiever.

Early on, observations hinted that quasars were unlike any previously known astronomical object. Their brightnesses change slightly over months or days, so the sources of their light had to be smaller than the distance light could travel in that time.

Once astronomers knew what to look for, they began to find quasars left and right. The first were radio sources (the name *quasar* comes from the acronym QSRS, for quasi-stellar radio source). However, similar objects without strong radio emission turn out to be more numerous and are known formally as quasi-stellar objects, or QSOs.

Astronomers discover new quasars by surveying the sky for starlike objects whose colors differ from ordinary stars. They also look for starlike objects associated with radio or x-ray emission, and for those whose unusual spectrum betrays a quasar nature. The latest catalog from Mira Veron-Cetty and Phillippe Veron at the Observatoire de Haute-Provence includes 13,000 quasars, a growing number that eventually should top 100,000 thanks to the ongoing Sloan Digital Sky Survey.

As astronomers' understanding of quasar properties grew, it gradually became clear that quasars are not as extreme and unique as they first seemed. Quasars fall among a group of related objects collectively called active galactic nuclei, or AGNs. These all release a large amount of energy from a small area in the center of the galaxy, well beyond what ordinary stars (including supernovae and neutron stars) produce over their life cycles.

In effect, quasars gave astronomers their first peek through the door at extreme astrophysics. Taken broadly, quasars and AGNs unite several unusual kinds of galaxies, while posing to astronomers a major challenge: understanding the "monster in the middle" — the central engine — that powers them all.

Quasars and Active Galaxies

In hindsight, astronomers already knew about two kinds of active galactic nuclei when quasars popped on the scene. In 1943, Carl Seyfert identified a small number of galaxies whose nuclei showed unusual spectra. These are now called Seyfert galaxies, and they comprise about 5 percent of all bright galaxies. Seyfert galaxies often show unusually small and bright nuclei, whose spectra reveal they contain glowing gas moving at velocities around 10,000 kilometers (6,000 miles) per second. The spectral lines do not match those found in interstellar gas lit by ultraviolet radiation from young stars. Instead, the spectral thumbprint requires a much more energetic source that produces x rays.

Over a wide range of brightness in Seyferts, astronomers find the same pattern — a central source of high-energy radiation and rapid gas motions in a small volume. One kind of Seyfert galaxy, known as type 1, shows spectral features almost identical to those seen in quasars. (In fact, distinguishing the most luminous Seyfert 1 galaxies from quasars is arbitrary.) The faintest known type 1 Seyfert nucleus was found by Alex Filippenko and Wallace Sargent during a survey of 500 bright galaxies from Palomar Observatory in San Diego County, California. It lies in the very disorganized, 10th-magnitude spiral galaxy NGC 4395 in Canes Venatici, shining scarcely brighter than the brightest known supergiant stars. Yet this Seyfert galaxy shares common features with the most powerful quasars, 100 million times brighter! As members of the computer industry put it, quasars have an extraordinarily scalable architecture.

> *QUASARS GAVE ASTRONOMERS THEIR FIRST PEEK THROUGH THE DOOR AT EXTREME ASTROPHYSICS.*

Quasars also show kinship with radio galaxies, the other long-known kind of AGN. One of radio astronomy's most striking early discoveries was that many cosmic radio sources came in pairs, aligned symmetrically around a central galaxy. This central galaxy is usually an elliptical (sometimes a disturbed one), and it may show an optical spectrum like a Seyfert galaxy. Higher-resolution radio observations show jets of material reaching from the nucleus to extensive radio lobes that can span more than a million light-years.

In some cases, the highest-resolution radio data show that material is still being ejected from the core along the jets at respectable fractions of the speed of light. This provides another important clue to the power source in AGNs — it can eject material for millions of years at a stretch along a single axis, like some kind of cosmic flywheel.

Powerplant Specs

Quasars, which share some features with active galactic nuclei, have two defining properties. The first is a large redshift, which implies great distance and therefore high luminosity. The second is a starlike appearance in ordinary telescopic photographs, with the nucleus far outshining the galaxy it lies within. Aside from their visual appearance, quasars also differ from ordinary galaxies in their spectra, which show broad emission lines from highly excited gas and an underlying blue continuous spectrum lacking the absorption lines from ordinary stars.

THE MAKING OF A BINARY QUASAR

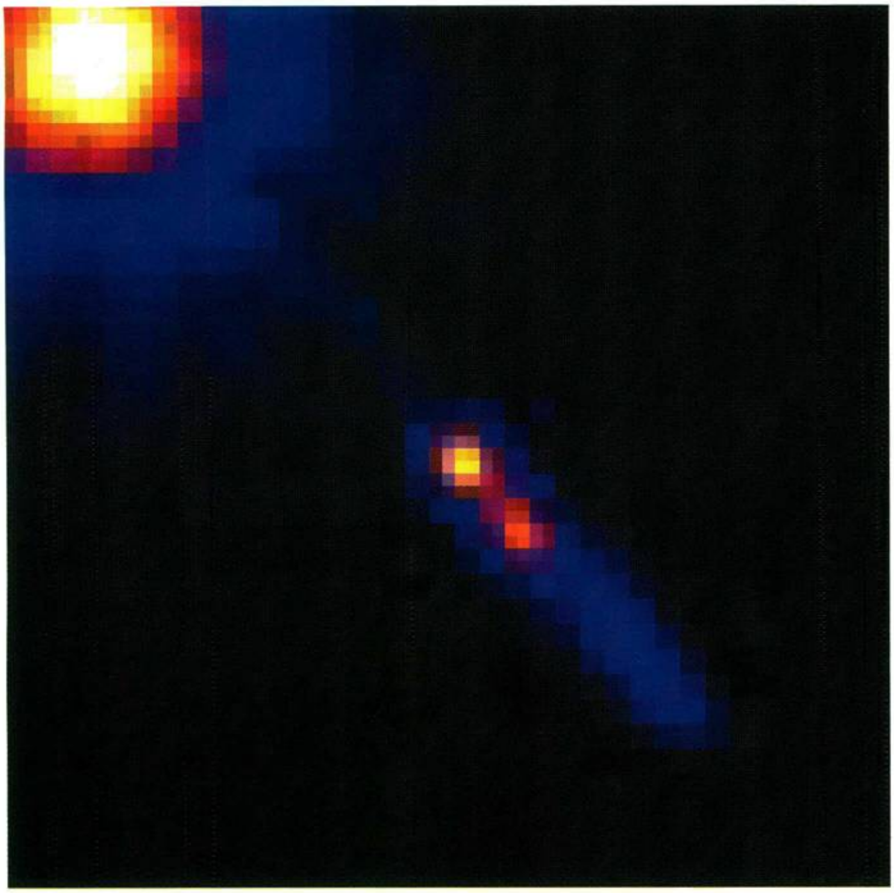
PART OF A GALAXY'S DESTINY IS TO COLLIDE with other galaxies. Astronomers envision a universe where small galaxies formed in the first few billion years after the Big Bang. These small galaxies repeatedly collided and merged, building up the large galaxies we see today. But what happens when two colliding galaxies both have supermassive black holes in their centers?

Computer simulations of galaxy collisions replicate the giant streamers of stars and far-flung gas seen in actual photographs. After one or two looping orbital passes, the two galaxies combine. During the orbits, gravitational forces drive gas into the center of each galaxy. This provides fuel for the black hole to spring back to life as an active galactic nucleus (AGN), or perhaps even as a quasar. If both galactic nuclei light up at once, the merging galaxies will become a binary quasar. The two quasars might be separated by about 30,000 to 300,000 light-years, or a spacing of 1" to 10" on the sky. Roughly a dozen such binary quasars are known, which works out to be about one per thousand normal quasars.

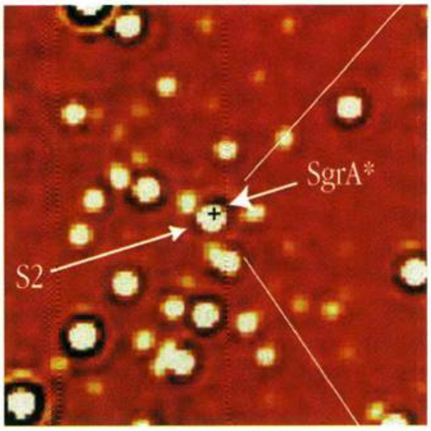
The quasars that form the binary pair LBQS 0103–2753 appear to be merging.

V. Junkkarinen et al.

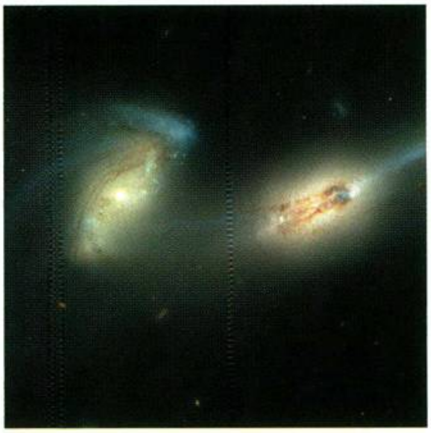
A striking example of a binary quasar was discovered recently using the Hubble Space Telescope. The team, led by Vesa Junkkarinen of the University of California–San Diego, was studying an 18th magnitude quasar known as LBQS 0103–2753. Hubble's sharp imaging revealed this object to be two quasars separated by only 0.3". This corresponds to a spacing of 7,500 light-years, much closer than any previously known binary quasar. The object evidently represents an advanced stage of a galactic merger, in which the galaxies have combined and the two galactic nuclei, with their respective black holes, are in the final stages of spiraling together. — *Gregory A. Shields is an astronomer at the University of Texas–Austin and a member of the team that discovered the binary nature of LBQS 0103–2753.*



In this x-ray image, a jet blasts from the first quasar identified, 3C 273. In 1963, unexplained lines in its spectrum were determined to be those of hydrogen, redshifted by 16 percent due to the quasar's distance. NASA/CXC/SAO/H. Marshall



Above right: Quasars are thought to be powered by matter falling into supermassive black holes. Recent observations of orbiting star S2 strengthened support for a black hole candidate, SgrA*, at the center of our own galaxy. ESO



When a black hole consumes all the matter around it, it stops radiating. If its host galaxy merges with another, however, as in the Mice galaxies above, it can reignite. Such a merger might also cause a binary quasar. NASA/ACS/ESA

Early quasar observations added a crucial piece to the puzzle. Despite shining far brighter than ordinary galaxies, quasars change brightness on short timescales. Indeed, their x-ray output can vary in *minutes*. As we've seen, this shows that most of the radiation must come from tiny regions, maybe no more than light-hours across, or roughly the orbit diameter of Uranus or Neptune.

Along with their small size, quasars must have central engines with gravitational fields strong enough to hold onto gas that's moving at thousands of kilometers per second. Also, the gas must be exposed to high temperatures or energetic radiation to create the observed spectral lines and x-ray emission. Finally, the extent and speed of the radio-emitting jets show that the source has a directional memory and can eject material so close to the speed of light that it escapes in spectacular fashion.

So what kind of object can do all this? The most reasonable explanation is an enormous black hole. Such an object contains so much mass packed so densely that even light can't escape. This gigantic black hole, grown in the dense core of a galaxy, would incorporate not the paltry few solar masses from a collapsed star, but millions or billions of solar masses. Gas coming close to such a monster would flatten into a disk orbiting the black hole. Collisions among atoms jostling in the accretion disk would heat them to very high temperatures, especially close to the black hole where orbital velocities rise toward the speed of light. As a bonus, calculations show that such a disk could amplify even small interstellar magnetic fields so as to launch some of the material at nearly the speed of light into twin jets perpendicular to the disk.

This general picture of active galactic nuclei — hot accretion disks around supermassive black holes — is widely accepted, but astronomers still have trouble connecting specific pieces of it to observations. Generally speaking, astronomers expect x rays to come from the hot inner parts of the disk, and ultraviolet and visible radiation to come from farther out where the disk is cooler. The strong emission lines must come from swirling gas clouds lit up by the ultraviolet and x-ray emission from closer in. Astronomers can trace the radio jets to within a light-year of the core, not much bigger than the scale of the accretion disk itself.

Although direct evidence remains elusive, there is little question about the black hole — its dynamical signs are abundant. Researchers now seek to compare black holes in active galaxies and their normal galactic counterparts. This is beginning to show how quasars and ordinary galaxies connect, and it hints that most galaxies went through an unruly quasar phase in their youth.

Unmasking the Unseen

Making a positive identification of a black hole is extraordinarily challenging for astronomers. Black holes can't be seen, only detected by their effects on surroundings — either by watching local

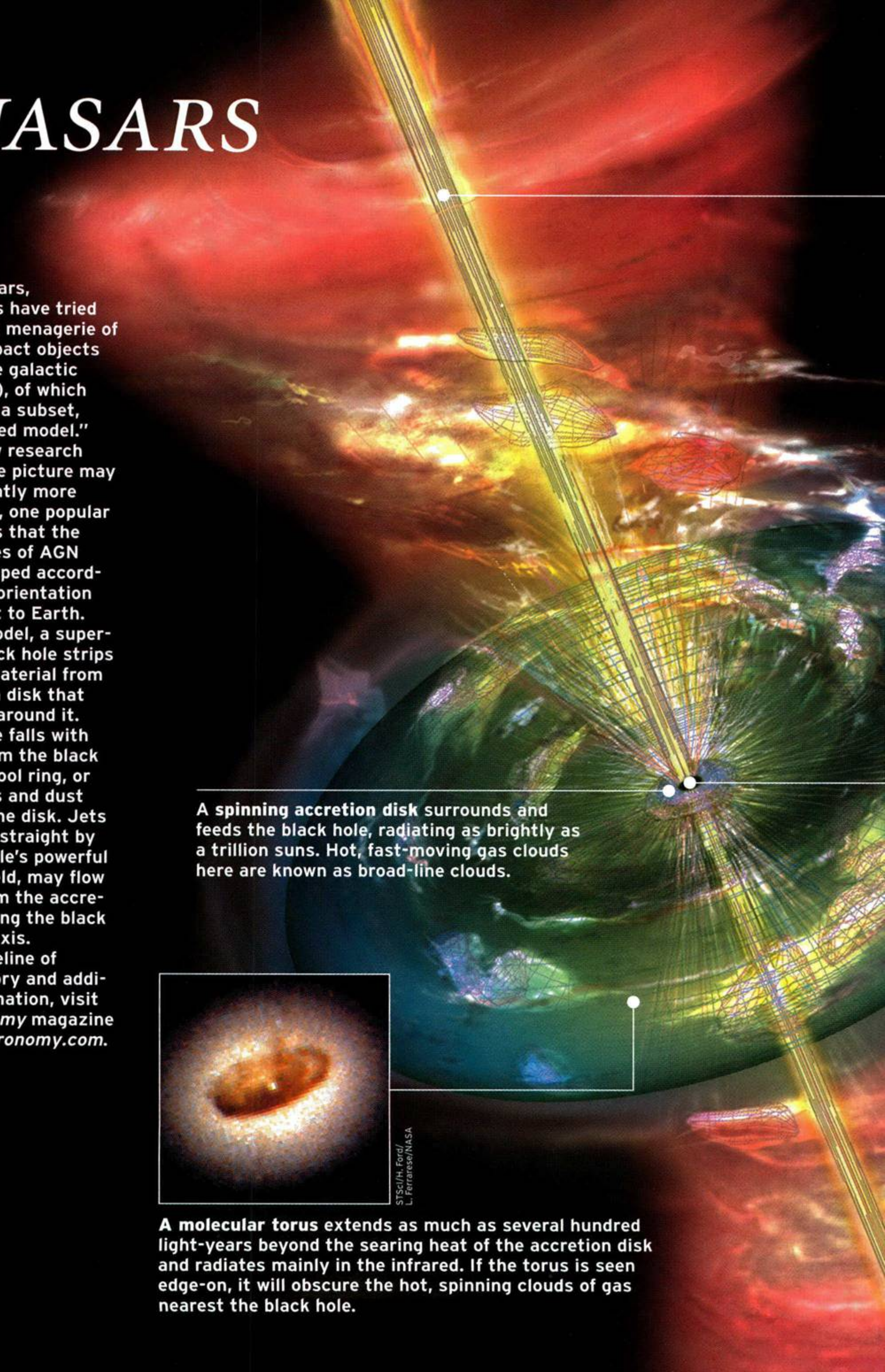
QUASARS

In recent years, astronomers have tried to classify a menagerie of bright, compact objects called active galactic nuclei (AGN), of which quasars are a subset, into a "unified model."

While new research suggests the picture may be significantly more complicated, one popular theory holds that the various types of AGN may be grouped according to their orientation with respect to Earth.

In this model, a supermassive black hole strips and heats material from an accretion disk that has formed around it. Temperature falls with distance from the black hole and a cool ring, or torus, of gas and dust surrounds the disk. Jets of gas, kept straight by the black hole's powerful magnetic field, may flow outward from the accretion disk along the black hole's spin axis.

For a timeline of quasar history and additional information, visit the *Astronomy* magazine page at *Astronomy.com*.



A spinning accretion disk surrounds and feeds the black hole, radiating as brightly as a trillion suns. Hot, fast-moving gas clouds here are known as broad-line clouds.

STScI/H. Ford/
L. Ferrarese/NASA

A molecular torus extends as much as several hundred light-years beyond the searing heat of the accretion disk and radiates mainly in the infrared. If the torus is seen edge-on, it will obscure the hot, spinning clouds of gas nearest the black hole.

NASA/STScI/AURA

Jets send matter gushing from the accretion disk along the black hole's spin axis. The jet above extends 8,000 light-years from the center of the giant elliptical galaxy M87. The material in jets like this can appear to move faster than light, an illusion caused by the fact that such jets are aimed toward Earth.

NASA/STScI

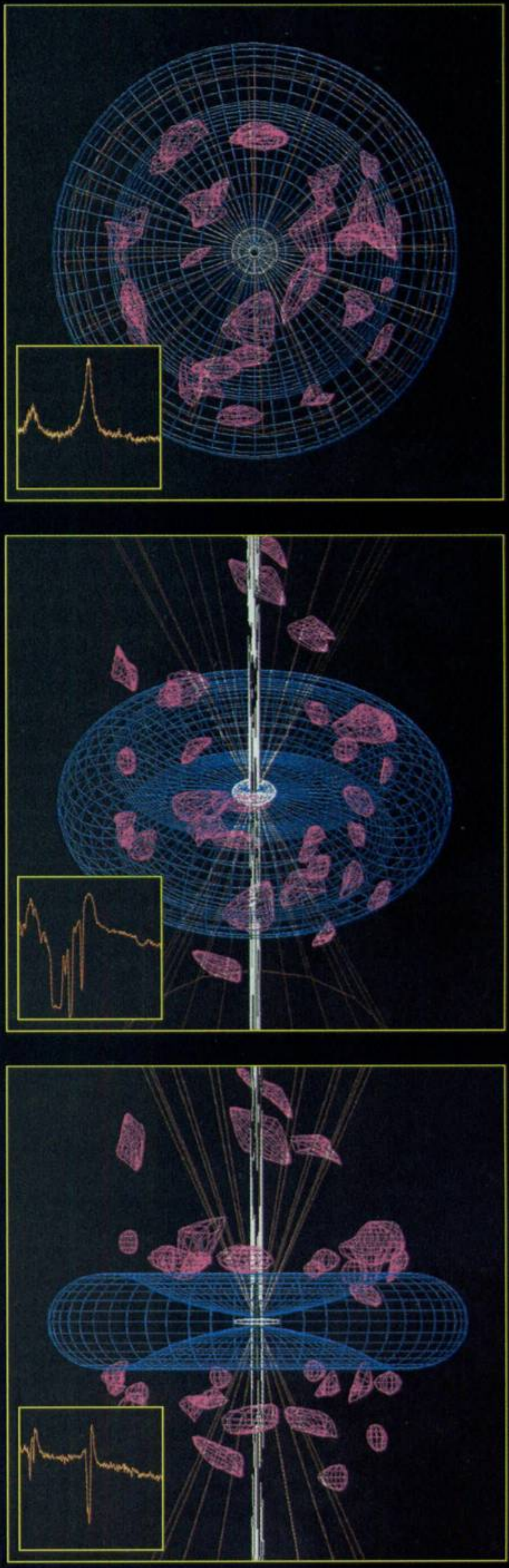
Narrow-line clouds are illuminated by light that spills out above and below the torus. Relatively slow-moving gas clouds in this region cause narrow absorption lines in the quasar's spectrum.

In theory, the type of AGN we see, identified by its spectrum, depends on the angle by which we view it.

Top: If we are looking into the jets, spectral lines from other regions may get washed out. BL Lacertae objects and optically violent variables fall into this category.

Middle: If the central region is angled toward us, we see the hot gas (broad-line clouds) near the accretion disk, as well as the narrow-line clouds farther out. Quasars, Type 1 Seyfert galaxies, and broad-line radio galaxies form this group.

Bottom: The torus blocks the scorching central region, so observers see narrow-line clouds above and below the disk. Radio-loud quasars, narrow-line radio galaxies, and Type 2 Seyferts comprise this group.



Astronomy: Roen Kelly / Spectra courtesy Beverley Wills, Michael Crenshaw, and Kirk Korista material accelerated by the powerful tug of their enormous mass, or by seeing passing light rays deflected by the curvature of space, which Einstein showed occurs near massive objects. If the general picture for quasars and their kin is correct, astronomers expect to see fireworks from the surroundings of some black holes. But how do they pinpoint a tiny object, impossible to see directly?

The strongest evidence comes from tracing the motions of stars and gas near black hole candidates. Astronomers used this approach to confirm the first stellar-mass black hole candidates in this galaxy, identified because they were strong x-ray sources. In these cases, the x rays arise in an accretion disk of material stripped from a companion star. Observations can detect the companion star and determine its orbit around the invisible component, thus giving the unseen object's mass using Kepler's laws. If that mass turns out greater than about three solar masses, the case is considered proven. No other object but a black hole could be so massive and remain invisible at all wavelengths.

Recently researchers measured the mass of the black hole at the center of the Milky Way. Using speckle interferometry and adaptive optics to sharpen the view, astronomers followed the rapid orbital motion of stars a fraction of a light-year from the center of our galaxy. Results by Rainer Schödel of Germany's Max-Planck-Institute for Extraterrestrial Physics and collaborators show that stars near the galactic center are affected by an invisible object of about 3.7 million solar masses. In the same way that Master Yoda and his disciples saw through an attempt to wipe a planet from the Jedi archives, astronomers can discern the existence of this object through its gravitational signature. Yet even at a mass of 3 million suns, this black hole proves quite modest by the standards of other galaxies.

How To Grow a Black Hole

More distant galaxies show traces of much more massive black holes. Astronomers map these using spectra from stars on either side of a black hole. As shown most clearly by John Magorrian, now at Britain's University of Durham, and co-workers, data from the Hubble Space Telescope reveal a surprising relation between the mass of the central object and the properties of the surrounding galaxy. In virtually every case, the central black hole comprises about 0.5 percent of the mass of the stars in the spheroid of the galaxy. (Recent detections of central black holes in some globular star clusters show that they, too, follow a similar ratio and perhaps have similar histories.)

A galaxy's spheroid is the roundish central bulge in a spiral galaxy, or the whole galaxy with an elliptical. The spheroid probably formed during an epoch of rapid star creation when the galaxy was young. The fixed numerical ratio, called the Magorrian relation, suggests the galaxy and its black hole somehow share a linked history. It may mean that the black holes were there first and attracted a closely proportional amount of material to make stars — or that the galaxy was there first and grew a central black hole whose size always stayed a constant fraction of the stellar mass. Which is more likely?

ASTRONOMERS WEREN'T SURE WHETHER QUASARS WERE MERELY INTERESTING OR ACTUALLY IMPORTANT.

Theory offers such a clear explanation of the second alternative that it seems vastly more probable. If we imagine a galaxy with a newborn central black hole, say one made by a single cluster's worth of stars merging, the black hole initially has little dynamical impact on its surroundings. As it grows, however, it eventually comes to dominate its immediate environs and alters orbits of nearby stars. Once the black hole reaches a particular maximum mass, calculations by David Merritt and Gerald Quinlan of Rutgers University show that it shuts off its own growth by forcing orbits of surrounding stars to become more circular. This keeps them out of the black hole's reach.

Merritt and Quinlan's computations follow the Magorrian relation, although they show the black hole stopping growth at a mass several times higher than the 0.5 percent typical of bright galaxies. (No result in astronomy ever fits perfectly.) In any case, if this process happened commonly, most galaxies must have undergone a bright quasarlike phase in their youth, when the central black hole was growing by ingesting material and producing quasarlike symptoms. The development of a central black hole may be an unavoidable part of a galaxy's formation and evolution.

Galaxies that hosted quasars in the early universe must have been special places. They were the first galaxies to pull themselves together and form stars in a dense core, and they could also grow a central black hole most rapidly.

Yet considerable mystery remains about the original formation and early growth of black holes. Calculations show they could grow rapidly by disrupting passing stars and accreting some of their matter — but only when they were already massive enough to exert strong tidal forces across interstellar distances. But quasars appeared very soon after the Big Bang. How could their central black holes grow so massive so quickly?

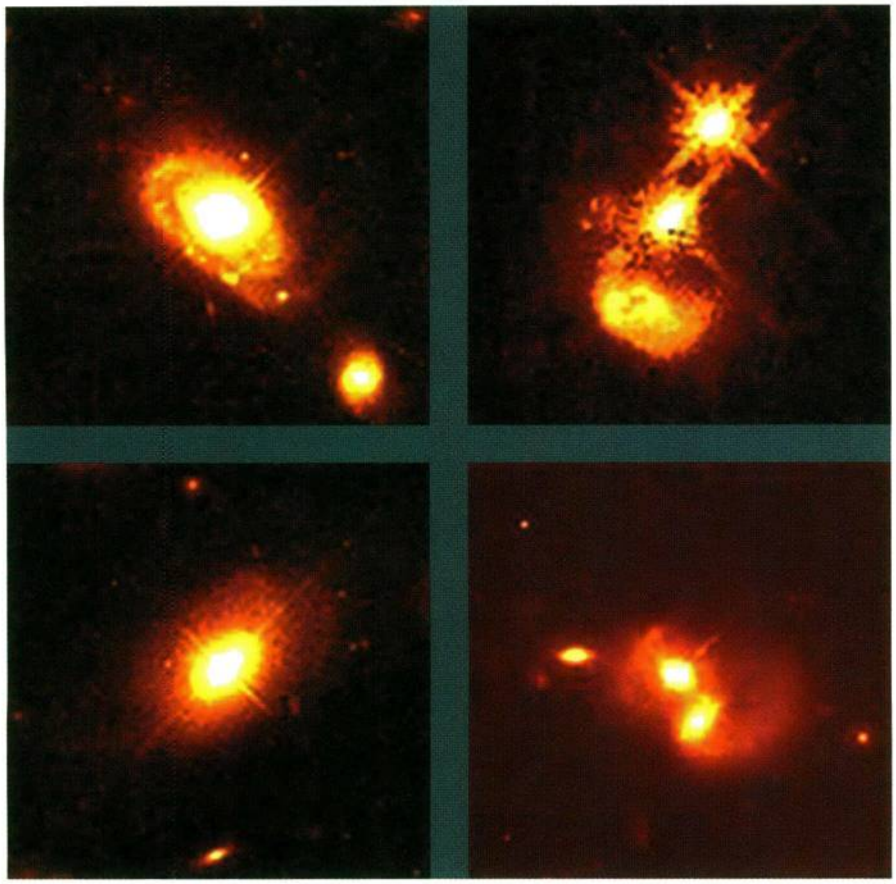
Relics of the Early Universe

One possible answer, now out of vogue, is that black holes may have simply started out big, as primordial relics of a chaotic early era. Perhaps they were the lumps of mass that seeded and accelerated the formation of galaxies.

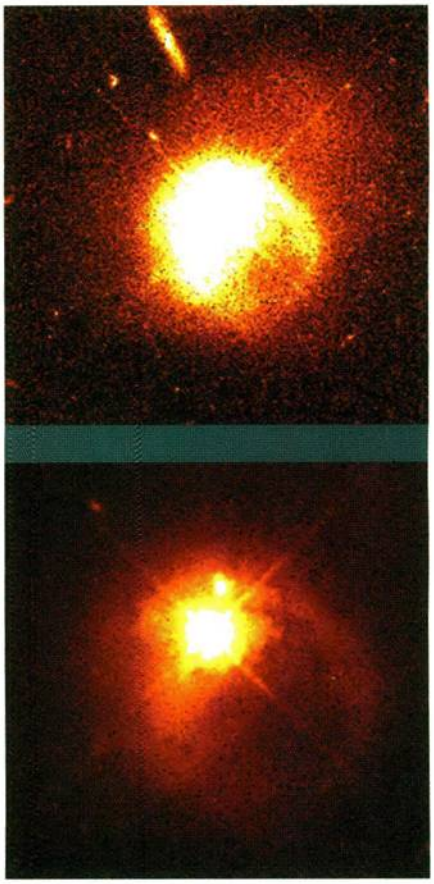
This notion was popular for several years when it seemed Hubble images showed some quasars with little or no surrounding galaxies. First came the quasar, then came the galaxy — or so it appeared. Further observations, however, found that all nearby quasars have substantial surrounding galaxies and as Magorrian found, the mass of the central object corresponds closely with the surrounding spheroid of stars. Thus it looks as if black holes have grown along with their galaxies' development.

Astronomers only recently found objects that bridge the gap between the "small" black holes made by single collapsing stars and the galactic ones massive enough to shred passing stars for breakfast. These intermediate-mass black holes were spotted in globular clusters, suggesting black holes in clusters form similarly to those in galaxies.

The most massive black hole that would result from the collapse of a single star would have perhaps 100 solar masses. Theory suggests that such massive stars are likely to form only among the first generation in the universe. (Later stellar generations contain chemical elements that discourage such massive stars from forming.) Unfortunately, because



Although quasars appear starlike in most telescopic views, longer exposures and those from the Hubble Space Telescope, above, reveal they lie within both normal (left column) and disrupted (right column) galaxies. Radio-loud quasars, constituting less than 10 percent of all quasars, are most often found in ellipticals. More than one-third of quasar host galaxies are found near small companions, suggesting interactions between them cause the quasars to flare. J. Bahcall/M. Disney/NASA



Like a moth to a flame, a small galaxy is drawn fatefully to the quasar PKS 2349. Top: The arms of the quasar's host galaxy are disturbed by its future prey, visible above the quasar (bottom). J. Bahcall/M. Disney/NASA

massive single stars explode powerfully as supernovae, astronomers don't expect to find their remnants within today's galaxies. In any case, even 100 solar masses fall well short of the roughly 100,000 solar masses needed to start devouring matter from other stars.

One way to bridge the gap might lie in the properties of relativistic star clusters, which are so compact and massive that relativity is needed to describe the motions and interactions of their members. If we could take a rich present-day star cluster, turn its members into neutron stars or black holes, and squeeze it into a volume just a couple of light-years across, we would get a relativistic cluster.

But forming such a cluster isn't easy. The process would start with an intense and compact burst of star formation, followed by the interaction of neutron stars or black holes. Somehow all these objects would stay together, with the most massive settling to the center in a process that accelerates as the cluster becomes relativistic.

Astronomers have long wondered about the stability of relativistic star clusters. Is it inevitable that such a cluster will fall together until its central members form one enormous black hole, or can such a cluster keep its members separate for cosmically long periods? At this point, no one can say.

The reason for even considering such extreme (and so far unobserved) collections of mass is that regions of very intense star formation lie in nearby galaxies. Loaded with massive stars, these mimic astronomers' conceptions of nascent galaxies at early times. Moreover, this kind of extreme environment matches the chemical makeup of the gas in quasars. This is an area ripe for further study, especially in the area of conditions in galaxies that formed soon after the Big Bang.

Interesting – or Important?

My graduate advisor, Joe Miller, once mused that we don't know whether quasars are merely interesting or actually important. For many scientists, no such distinction exists. But Joe meant that it wasn't clear that active galaxies were part of the path that led to the most precious of all cosmic phenomena — life.

Do quasars and active galaxies reflect the same properties of the universe that allow us to exist? Or could we exist if the universe had been such as *not* to bring forth these powerhouses? No one yet knows.

Quasars and their kin have proven highly interesting, from testing relativity through probing intergalactic gas to tracing the history of galaxies. Signs indicate they may even be important, and that the next 40 years of our exploration will yield a richer view than we can conceive of now.

William Keel is an astronomer at the University of Alabama who studies the evolution and properties of galaxies. His new book, The Road to Galaxy Formation, *explores how closely linked black holes and galaxy growth might be.*

WHEN STARS EXPLODE

As a star rips itself apart, the blinding flash can be seen across the universe.

by Alexei V. Filippenko

OUR SUN, A TYPICAL STAR, WILL CONTINUE TO SHINE MUCH AS it does now for another five billion years. It will then become a red giant, expanding to a size larger than the orbits of Mercury and Venus, and growing so luminous that it will literally fry Earth's surface.

Shedding its outer envelope through winds and a series of cosmic burps, it will produce a planetary nebula — a balloon of ionized gas like the famous Ring Nebula (M57) in Lyra. All that will remain is a small, dense white dwarf consisting of a carbon and oxygen core and a helium shell, the products of nuclear burning that sustained the Sun's power for billions of years.

Having no new energy source, the white dwarf will gradually cool and fade, ending up as a dark rock hurtling through space essentially forever. Thus, despite a burst of glory in old age, the Sun's death will be relatively quiescent. The same can be said for the majority of all stars.

In some cases, however, stars can go out with a bang — explosions as violent as any except the Big Bang itself. Some of these so-called supernovae release as much energy in one second as all the other stars in the observable part of the universe. For several weeks they can rival the visual brightness of an entire galaxy containing hundreds of billions of stars. The outer layers of gas get heated to temperatures exceeding one hundred thousand degrees and are ejected at speeds up to nearly 20,000 miles per second — one-tenth the speed of light. A recent, well-studied example is Supernova 1987A in the Large Magellanic Cloud — the brightest supernova to grace our skies since Kepler's supernova in 1604.

During a supernova explosion, thermonuclear reactions synthesize heavy elements such as gold, iron, and oxygen. These elements, together with others created deep within the stars prior to their final demise, are ejected into the cosmos, providing the raw material from which earthlike planets and life can form. It is no exaggeration to say that we owe our existence to supernovae.

Yet people who study supernovae realize this simple picture is incomplete. Supernovae show a broad range of characteristics in how they brighten and fade, in the elements they create, and even in the environment they inhabit. Much like ornithologists who categorize birds beyond their ability to fly, astronomers seek to understand the inner workings of the different species of exploding stars.

A Supernova Field Guide

It may come as a surprise that supernovae are not classified according to obvious differences in how their light output changes with time, where they occur, or even the mechanism that causes them to explode. Instead, astronomers base their classification primarily on differences in their optical spectra.

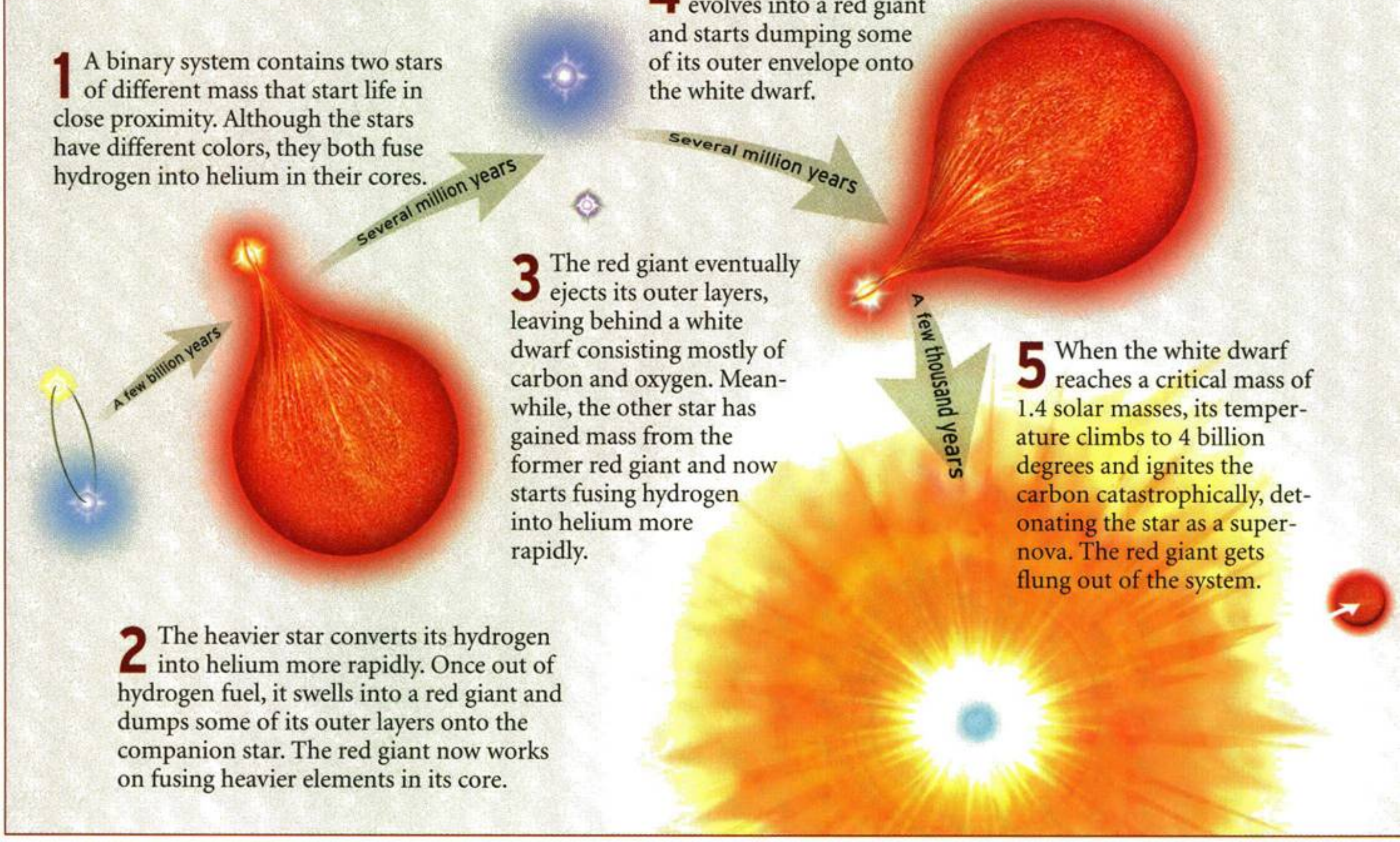
Astronomers naturally choose to focus on hydrogen, by far the most abundant element in the universe. If a supernova's spectrum does not exhibit any broad absorption lines (valleys) or emission lines (peaks) corresponding to hydrogen, the exploding star is called Type I. If hydrogen is present, either in emission or absorption, it is called Type II. The width of the lines, which provides a sensitive measure of how fast the material moves, tells us that the gases are expanding at speeds exceeding 3,000 miles (5,000 kilometers) per second, and in some objects reach 18,000 miles (30,000 km) per second.

Of course, not all objects whose spectra lack hydrogen are physically devoid of hydrogen. The atmospheres of O-type stars, for example, are too hot for hydrogen lines to form in their visible-light spectra, while the atmospheres of M-type stars are too cool. However, detailed analyses of the spectra of Type I supernovae demonstrate that hydrogen really is absent, or nearly so, in their progenitor stars just before they explode. Thus, Type I and Type II supernovae appear to be genuinely different kinds of beasts.

Rudolph Minkowski of the Mt. Wilson and Palomar Observatories proposed this classification scheme back in 1941. His temperamental colleague, Fritz Zwicky, an avid supernova sleuth, discovered 122 supernovae — a record for individuals

Debris from Supernova 1987A rushes outward toward three rings of material ejected from its massive progenitor star thousands of years before the explosion. NASA and the Hubble Heritage Team (STScI/AURA)

TYPE IA SUPERNOVA



1 A binary system contains two stars of different mass that start life in close proximity. Although the stars have different colors, they both fuse hydrogen into helium in their cores.

2 The heavier star converts its hydrogen into helium more rapidly. Once out of hydrogen fuel, it swells into a red giant and dumps some of its outer layers onto the companion star. The red giant now works on fusing heavier elements in its core.

3 The red giant eventually ejects its outer layers, leaving behind a white dwarf consisting mostly of carbon and oxygen. Meanwhile, the other star has gained mass from the former red giant and now starts fusing hydrogen into helium more rapidly.

4 The second star now evolves into a red giant and starts dumping some of its outer envelope onto the white dwarf.

5 When the white dwarf reaches a critical mass of 1.4 solar masses, its temperature climbs to 4 billion degrees and ignites the carbon catastrophically, detonating the star as a supernova. The red giant gets flung out of the system.

that remains unbeaten. Zwicky created three additional classes (which he called Type III, IV, and V), but only one or two examples existed of each, so astronomers now consider them to be members of the Type II class.

Drawing a Distinction

Type I supernovae appear remarkably similar to each other. During the first month or two after the explosion, lines of silicon, sulfur, calcium, oxygen, and magnesium dominate their spectra. Although the detailed appearance of the spectrum changes gradually, the spectroscopic similarities among different Type Is at any given time after the explosion are striking.

In the 1960s, however, astronomers began to realize that the spectra of some Type I supernovae exhibited peculiarities during the first several weeks following the explosion. Unlike normal Type Is, these deviants seemed to lack a deep absorption line in the red region of the spectrum around 6100 angstroms, now attributed to singly ionized silicon atoms. Unfortunately, these oddballs were largely ignored until the mid-1980s, when several new examples were found. Astronomers dubbed the peculiar objects Type Ib supernovae, to distinguish them from the classical Type I supernovae, now called Type Ia.

J. Craig Wheeler of the University of Texas and his colleagues made a breakthrough when they discovered that, early on, the spectra of Type Ib supernovae show prominent absorption lines of neutral helium. The second most abundant element in the universe, helium is absent in Type Ia supernovae spectra.

But further complications were in store. In the late 1980s, astronomers saw that some of the Type I supernovae that lack the silicon absorption line in their spectra also lack helium — suggesting yet another observationally distinct subclass, Type Ic, should be defined.

Many months after the explosion, blends of iron and cobalt emission lines dominate the optical spectra of Type Ia supernovae. This differs greatly from Type Ic supernovae, which exhibit strong emission lines of intermediate-mass elements, especially oxygen and calcium. However, despite the fairly clear distinction between Type Ib and Ic supernovae at early times, later on the differences are subtle, if present at all.

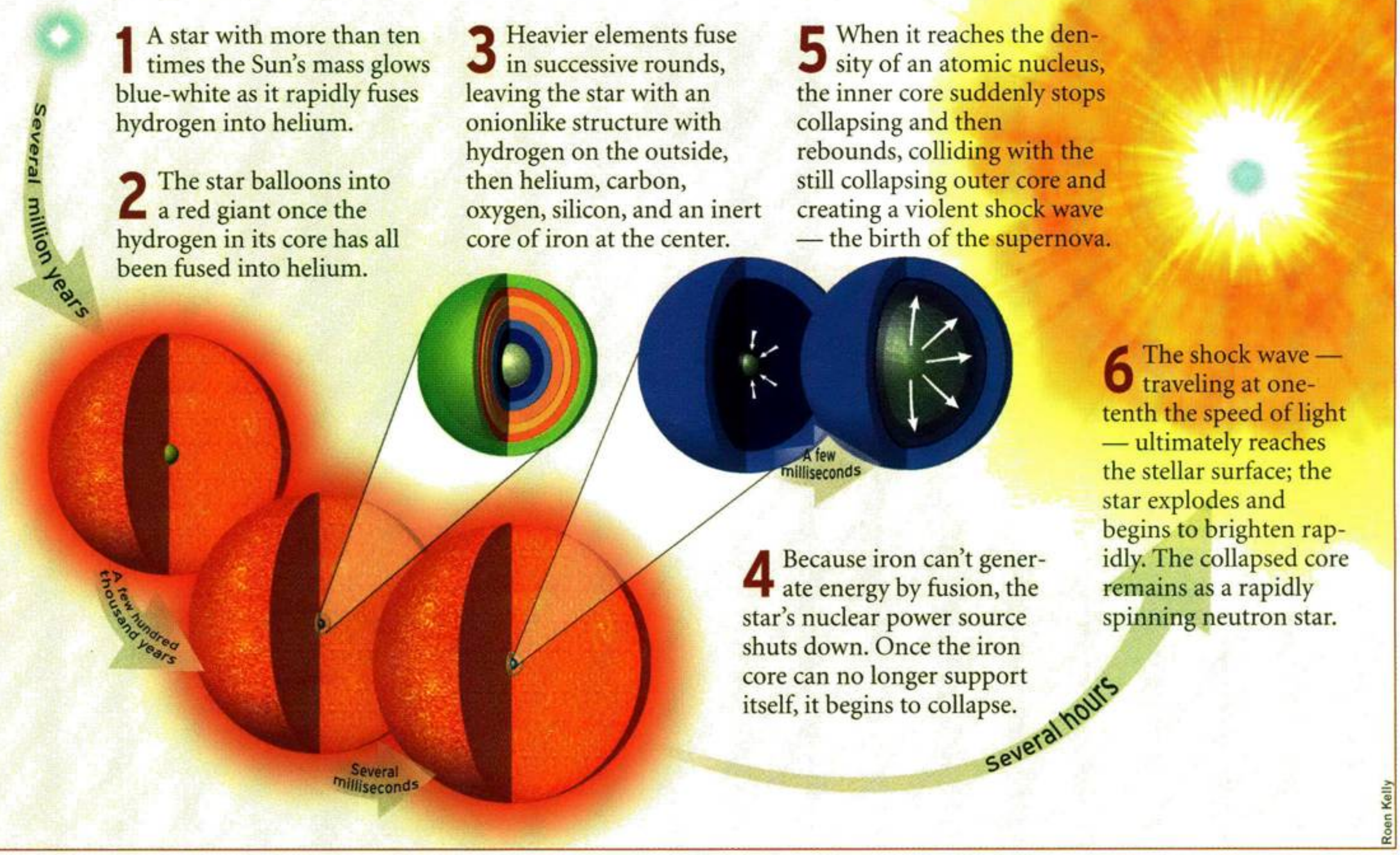
Astronomers have not yet adopted formal subclasses for Type II supernovae, partly because these objects display a wide range of observed properties. Nevertheless, the spectra do seem to fall into two broad, but relatively distinct, groups.

The largest group consists of those whose spectra exhibit "P-Cygni" profiles of hydrogen and other elements. Such profiles show emission centered roughly on the wavelength observed in a laboratory together with an absorption trough just to the shorter wavelength side. Named after the prototype star, P Cygni, these profiles are produced when gas flows rapidly outward (in a wind or explosion, for example) from an otherwise normal source.

Far rarer are Type II supernovae dominated by emission lines on an otherwise featureless spectrum — absorption lines are weak or absent. Although researchers don't yet have a good understanding of these objects, it seems their unusual spectra are at least partly caused by the presence of considerable circumstellar gas — perhaps a slow, unusually dense wind that emanates from the progenitor star.

Until recently, astronomers thought supernovae do not change from one type to another as they evolve. For example,

TYPE II SUPERNOVA



1 A star with more than ten times the Sun's mass glows blue-white as it rapidly fuses hydrogen into helium.

2 The star balloons into a red giant once the hydrogen in its core has all been fused into helium.

3 Heavier elements fuse in successive rounds, leaving the star with an onionlike structure with hydrogen on the outside, then helium, carbon, oxygen, silicon, and an inert core of iron at the center.

4 Because iron can't generate energy by fusion, the star's nuclear power source shuts down. Once the iron core can no longer support itself, it begins to collapse.

5 When it reaches the density of an atomic nucleus, the inner core suddenly stops collapsing and then rebounds, colliding with the still collapsing outer core and creating a violent shock wave — the birth of the supernova.

6 The shock wave — traveling at one-tenth the speed of light — ultimately reaches the stellar surface; the star explodes and begins to brighten rapidly. The collapsed core remains as a rapidly spinning neutron star.

Roen Kelly

Type II supernovae continue to exhibit hydrogen in their optical spectra long after they explode, while the ejecta of Type I supernovae never contain noticeable quantities of hydrogen. A complication arose, however, with Supernova 1987K. (Astronomers designate supernovae by their year of occurrence, with a letter or letters denoting the order of their discovery.)

Discovered in galaxy NGC 4651 in Coma Berenices near the end of July 1987, SN 1987K reached nearly 14th magnitude at maximum brightness. It was an easy spectroscopic target for my team, and we promptly classified it as a Type II — hydrogen was present, with a classic P-Cygni profile.

Unfortunately, we could not continue observing SN 1987K past the middle of August, when Coma Berenices gets too close to the Sun to observe. The next opportunity to view SN 1987K came on December 25, 1987 — what a terrific Christmas present! Remarkably, the spectrum showed no trace of broad hydrogen lines. SN 1987K now looked like a Type Ib (or Type Ic) supernova; it had undergone a unique transformation.

The second unambiguous example of this phenomenon came six years later, with the bright SN 1993J in M81. Hydrogen lines were easily visible in spectra taken one to four weeks after the explosion — but the hydrogen-alpha line did not strengthen progressively relative to other features as in normal Type II supernovae. Instead, helium absorption lines began to appear, suggesting that the outer envelope of hydrogen (which hides the deeper helium layer) was unusually thin.

My colleague Thomas Matheson and I predicted that, within several months, the spectrum of SN 1993J would closely resemble the spectra of Type Ib (or Ic) supernovae of the same age. We were right. Type II supernovae that undergo such a metamorphosis have been dubbed Type IIb to distinguish them from normal Type II supernovae that always show hydrogen in their spectra.

Seeing the Light

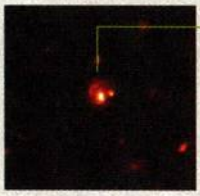
Although astronomers classify supernovae primarily by their spectra, the way their light output changes with time also plays a role. The light curves of most Type I supernovae (especially Ia, but also including Ib and Ic) appear roughly the same, although exceptions have been found. After a rise that lasts nearly three weeks, Type Is reach maximum brightness and immediately begin to fade. They dim rapidly for about a month, then more gradually.

Type II supernovae, on the other hand, show a variety of light curves that fall into two main groups. The rare Type II "linear" (II-L) supernovae show a rapid rise to maximum followed by a steep decline in brightness, mimicking their Type I cousins. In the more common Type II "plateau" (II-P) objects, the brightness remains nearly constant for two to three months.

Supernova 1987A was a variant of Type II-P; it actually grew *brighter* for several months because its initial maximum was unusually faint, a result of its progenitor star being a more compact blue supergiant instead of a typical red supergiant. SN 1993J was a different sort of variant of Type II-P, with a dip in the plateau that gave the light curve a peculiar double-peaked appearance. This dip resulted from the low mass of the hydrogen envelope in the progenitor star.

Of the two types, Type Ia supernovae are the most luminous. This property, combined with their nearly identical light curves, makes them reasonably good "standard candles" with which to

THE UNIVERSE ON HYPERDRIVE



Detailed studies of supernovae in the far reaches of the universe suggest the expansion rate of the universe is accelerating. Peter Garnavich, Harvard-Smithsonian Center for Astrophysics, the High-z Supernova Search Team, and NASA

ALBERT EINSTEIN ONCE CALLED IT HIS GREATEST blunder, and most astronomers long hoped it would just go away. But it now looks fairly certain that the cosmological constant — a mysterious pressure that pervades the universe and causes space to expand faster as time goes on — is real.

The critical evidence comes from observations of Type Ia supernovae. All these supernovae arise when a white dwarf gains enough mass to push it over the Chandrasekhar limit of 1.4 solar masses. Because the thermonuclear runaway always starts from the same configuration, the resulting supernovae should all have similar brightnesses, making them excellent standard candles.

Astronomers first observe how bright a Type Ia appears, then compare that with how luminous it actually is. This yields a good measurement of how far away the supernova lies and thus the distance to its host galaxy. For the past five years, two teams of researchers — one led by Saul Perlmutter of the Lawrence Berkeley Lab in California, the other by Brian Schmidt of the Mount Stromlo and Siding Spring Observatories in Australia — have been doing just that.

They have now examined hundreds of Type Ia supernovae, some that exploded when the universe was merely half its current age. The researchers have found that the most distant supernovae are 10 to 20 percent fainter than expected based on the redshift of their host galaxy (another good measure of distance). In other words, the expansion of the universe seems to be speeding up, pushing the galaxies farther away than predicted if gravity alone controlled the expansion rate.

It's a weird concept, but one that appears to be real. Astronomers even have a name for it, usually discarding Einstein's cosmological constant and calling it dark energy. But whatever its name, we can thank Type Ia supernovae for our discovery of the accelerating universe. — *Richard Talcott*

measure large distances in the universe (see "The Universe on Hyperdrive," above). Type Ib and Ic supernovae seem to be about one quarter as luminous as Type Ia supernovae. Typically, the optical luminosity of Type IIs is similar to that of Type Ib and Ic supernovae, but they do exhibit a wide variation.

How to Make a Star Explode

What do these different characteristics tell us about the explosion mechanisms of supernovae? Clues come not only from the spectra and light curves of the supernovae, but also from the environments in which the stars explode.

Type Ia supernovae occur in all kinds of galaxies, including ellipticals, which seem to contain primarily old stars and very little gas for making new ones. In spiral galaxies, Type Ia supernovae show no clear preference for regions of current star formation, where the most massive stars live and die. This, together with the absence of hydrogen in their spectra, suggests that we are witnessing the explosion of white dwarfs — old stars that have moved far away from their birthplaces. The uniformity of the light curves and spectra of Type Ia supernovae further implies that the white dwarfs achieve a well-defined configuration prior to exploding.

The leading hypothesis is that a Type Ia supernova results from an uncontrolled chain of thermonuclear reactions in a white dwarf that consists primarily of carbon and oxygen. This runaway is triggered when the white dwarf's mass reaches 1.4 solar masses, known as the Chandrasekhar limit after the Indian-American astrophysicist Subrahmanyan Chandrasekhar. (Chandrasekhar won the 1983 Nobel Prize in Physics for calculating the maximum possible mass for a white dwarf.) The white dwarf probably gains mass by accreting gas from a companion star in a binary system, although the exact details of this process (including the exact nature of the companion) remain a mystery.

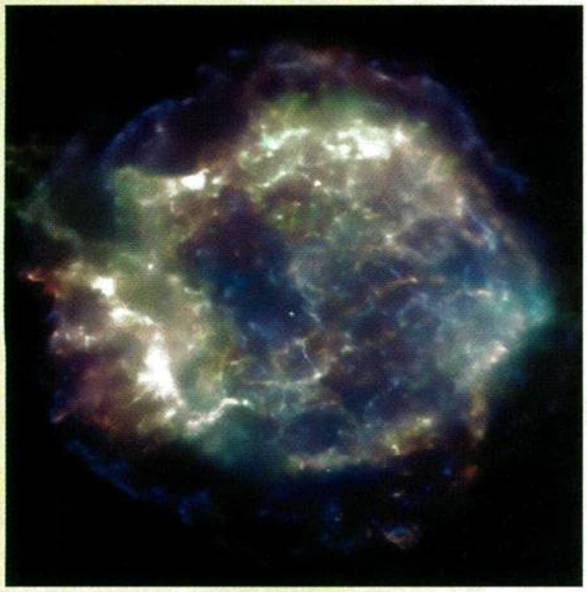
The rapid nuclear fusion of light elements provides enough energy to blast the star apart, as well as to synthesize heavy elements like silver, gold, and uranium. A large amount of radioactive nickel is also created, and its subsequent decay into radioactive cobalt and stable iron powers the optical light curve. This explosion mechanism does *not* leave behind a compact remnant such as a neutron star or black hole.

Type II supernovae are always found in spiral or irregular galaxies, usually in spiral arms and near regions of ionized hydrogen where stars are actively forming. This implies that they are associated with massive stars, whose lives are so short they don't have a chance to wander far from their birthplaces before exploding. The differences in the spectra and light curves of Type II supernovae are consistent with the wide range of sizes and circumstellar wind densities expected for stars exceeding 10 solar masses.

In the cores of massive stars, hydrogen fuses to helium, helium to carbon and oxygen, and so on up to iron. The ashes of one set of nuclear reactions become the fuel for the next set, and an onionlike radial structure develops. However, this process stops at iron, the most tightly bound nucleus. An iron core builds up in the star, which by this time has generally become a red supergiant with a diameter up to 1,000 times larger than the Sun.

But the iron core cannot continue to grow indefinitely. When it reaches a mass comparable to the Chandrasekhar limit for white dwarfs, it can no longer support itself. The core collapses, electrons are driven into the nuclei of the iron atoms, where they combine with protons to form neutrons and neutrinos, and the neutrinos escape immediately. In the process, the core releases a tremendous amount of energy.

When the density of the central region exceeds that of an atomic nucleus, it rebounds like a basketball dropped onto the floor. Smashing into the surrounding material, this creates an outward moving shock wave that reverses the collapse and leads to an energetic expansion. A similar effect can be seen if a tennis ball is placed on top of a basketball and both are dropped simultaneously. The copious neutrinos emitted by the exceedingly hot (100 billion degrees) neutron star probably help eject the layers of gas surrounding the core. Inside the



The chaotic debris of the Cassiopeia A supernova remnant testifies to the enormity of this Type II explosion. NASA/CXC/SAO

expanding fireball, atomic nuclei collide at high speed and synthesize heavier elements, although their relative proportions differ from those in Type Ia supernovae.

Despite some remaining uncertainties in the details, most experts are confident that Type II supernovae explode roughly in this manner — largely thanks to careful studies of SN 1987A, only 160,000 light-years away. The progenitor of SN 1987A was known to be an evolved star whose initial mass was about 20 times the mass of the Sun. Moreover, neutrinos were detected from SN 1987A in the expected quantities, showing that a neutron star formed, at least temporarily. (It may have subsequently collapsed into a black hole.) Finally, gamma rays from short-lived, radioactive cobalt nuclei were observed, providing dramatic proof that heavy elements were synthesized. Astronomers have yet to test the theory of Type Ia supernovae exhaustively, lacking a nearby example that can be studied with a wide variety of telescopes.

Stripping a Progenitor

Astronomers long thought that the observational division into Type I and Type II supernovae based on hydrogen neatly and conveniently corresponded to the two different explosion mechanisms: thermonuclear runaway for the former and core collapse for the latter. The discovery of Type Ib and Ic supernovae seriously complicated the situation.

The superficial resemblance between Type Ia and Type Ib/Ic supernovae led some theorists to propose that all three varieties result from thermonuclear runaway in white dwarfs. In this scenario, the observed differences might be caused by variations in the structure of the progenitor white dwarfs, or in the details of the nuclear burning.

Other astronomers, however, suggest that Type Ib and Ic supernovae may result from core collapse in massive stars that somehow lost their outer layers of hydrogen. This would agree with observations that show Type Ib/Ic supernovae never occur in elliptical galaxies and generally lie close to spiral arms or regions of ionized hydrogen, like Type II supernovae.

The outer layers could be lost through a strong stellar wind, but this probably works only for stars with at least 30 times the mass of the Sun. A less massive star could be stripped of its envelope by transferring it to a companion star, if it happens to be in a binary system. If most of the mass loss occurred late in the star's life, core collapse would proceed in the same manner as in massive, hydrogen-rich stars.

The hybrid supernovae 1987K and 1993J leave little doubt that most, if not all, Type Ib and Ic supernovae are actually more closely related to Type II than to Type Ia objects. Their spectra in the first couple of months after explosion clearly place them in the Type II category, suggesting core collapse as the explosion mechanism, yet their later spectra are virtually indistinguishable from those of Type Ib/Ic supernovae. Independent calculations by several research teams convincingly show that the progenitor of SN 1993J initially had about 15 solar masses, yet it lost most of this to a companion star separated by no more than 1 billion miles.

A core collapse (rather than thermonuclear runaway) origin for Type Ib and Ic supernovae has several important implications in other areas of astrophysics. For example, it explains why neutron stars and black holes are more common than the value derived from the birthrate of Type II supernovae alone. Similarly, the probability of detecting a burst of neutrinos from a core-collapse supernova in the Milky Way Galaxy increases, because not all of the Type I supernovae result from exploding white dwarfs. Models of the chemical evolution of galaxies are also affected because Type II, Ib, and Ic supernovae produce different relative abundances of the elements (such as a higher oxygen-to-iron ratio) than Type Ia supernovae. Finally, researchers attempting to use Type Ia supernovae as standard candles for cosmological studies must be careful to weed out the non-standard Type Ib and Ic objects.

What the Future Holds

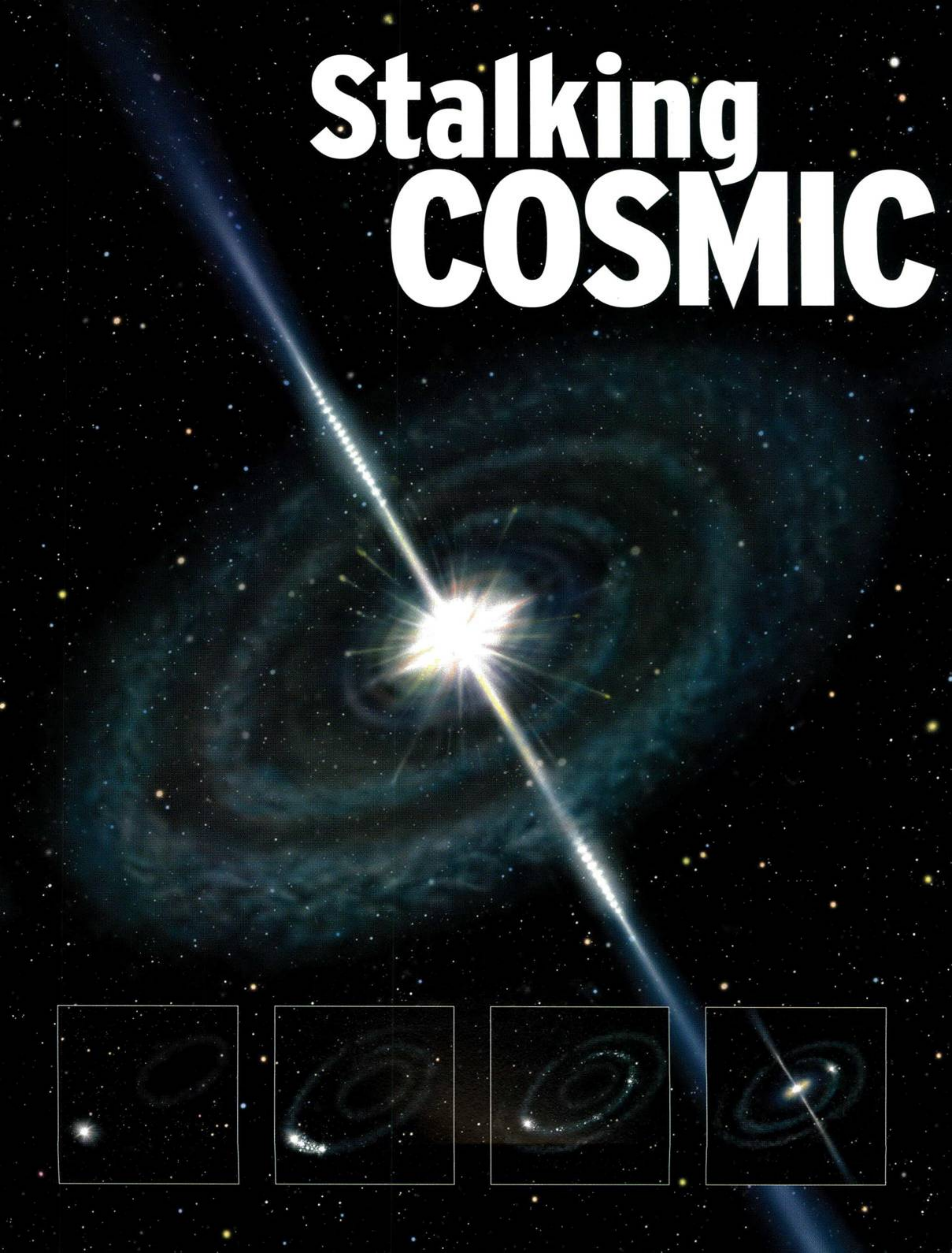
We have learned a great deal about supernovae during the past few decades, but our understanding remains far from complete. There is evidence, for example, that not all Type Ia supernovae are identical — a few that appear significantly fainter have been found, suggesting that some white dwarfs may have figured out how to explode before reaching the Chandrasekhar limit.

One indication that exciting discoveries lie ahead is that both of the brightest, nearest, and best-studied recent supernovae (SN 1987A and SN 1993J) turned out to be peculiar and taught us a great deal about stellar explosions. It seems plausible that many additional varieties of peculiar supernovae are out there. Will future supernovae in the nearby universe provide astronomers with as much information as SN 1987A and SN 1993J? Only time will tell.

I wish Fritz Zwicky were alive today. He loved to examine the spectra and light curves of supernovae — classifying them, trying to identify new types, and searching for clues to the nature of the explosions. With the advanced detectors now available, the quality of data is better by orders of magnitude, and dozens of supernovae can be studied each year. He would have had a grand time. ■

Alexei V. Filippenko is Professor of Astronomy at the University of California-Berkeley. His main research interests are in determining the nature of the progenitor stars, the explosion mechanisms, and the products of different types of supernovae.

Stalking COSMIC

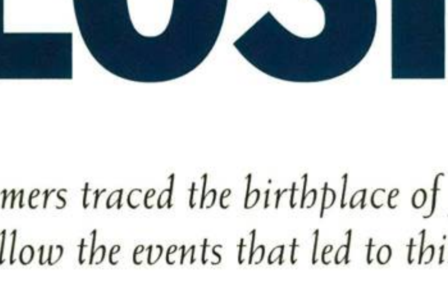


EXPLOSIONS

In 1997, astronomers traced the birthplace of gamma-ray bursts to distant galaxies. Follow the events that led to this monumental discovery.

By Govert Schilling

On Friday February 28, 1997, the Astronomical Institute "Anton Pannekoek" at the University of Amsterdam was a madhouse. In the morning new observations from the La Palma observatory in the Canary Islands came in. Paul Groot and Titus Galama, two graduate students of prominent astrophysicist Jan van Paradijs, started to analyze the data. John Telting, a staff astronomer at La Palma, had photographed a tiny area of sky in the constellation Serpens, where a gamma-ray burst had occurred on January 11 (GRB 970111). Earlier searches for a radio afterglow of this burst, using the Dutch Westerbork Synthesis Radio Telescope (WSRT), had been unsuccessful, but scientists remained hopeful an optical afterglow would show up.



The William Herschel Telescope on La Palma helped astronomers locate the first optical afterglow of a gamma-ray burst. Javier Méndez

Around 11:00 P.M., Groot and Galama got an e-mail from Jean in 't Zand of the Space Research Organization Netherlands (SRON) in Utrecht, where the two Wide Field X-ray Cameras (WFCs) of BeppoSAX had been built. The night before, at 2:58 Universal Time, one of the cameras had observed a gamma-ray burst that lasted about 80 seconds in the northwest portion of the constellation Orion. So it seemed that here again was a new opportunity to find an afterglow, which would help astronomers pinpoint the location of a gamma-ray burst.

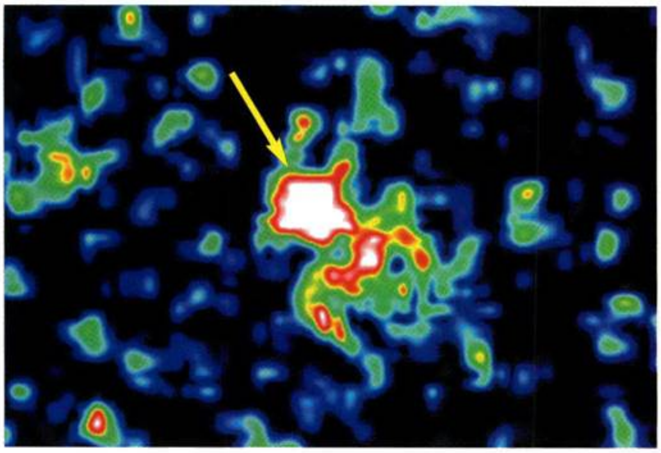
On that same night, Jean in 't Zand had been roused from his bed by a call from Enrico Costa of the Italian Istituto di Astrofisica Spaziale (IAS) in Rome, the principal investigator of the Gamma Ray Burst Monitor on board BeppoSAX, an x-ray satellite launched in 1996. A burst had been found in the field of view of one of the Wide Field Cameras. If the WFCs had seen a simultaneous x-ray burst, a more accurate sky position could be determined. The WFC measurements were quickly sent to Utrecht, and with the help of in 't Zand's software the position of the gamma-ray burst was precisely located to within a few arcminutes. On the basis of these calculations, BeppoSAX was turned so that the area from which the burst came could also be observed with the narrow-angle x-ray telescopes on the satellite.

There was one problem. In January, WFC project scientist John Heise of SRON had argued with Costa about giving out the sky position of GRB 970111 to van Paradijs's group. Costa considered this information to be proprietary; he wanted to search for afterglows with his own collaborators. Now, Heise didn't dare give a gamma-ray burst position to his Amsterdam colleagues again. "We even hesitated to call van Paradijs," says Heise. "Finally we decided that we would report that a new gamma-ray burst had been co-observed, but we would refrain from giving its exact position." If the Amsterdam group wanted to track down an afterglow, they would have to make contact with Costa and Luigi Piro, project scientist on BeppoSAX.

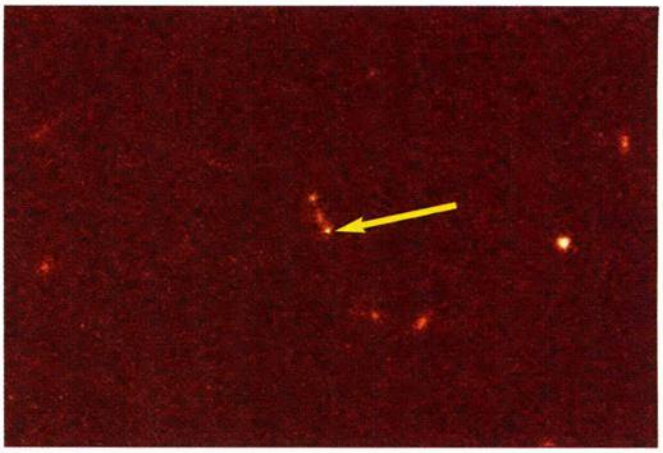
But van Paradijs wasn't in Amsterdam. He was asleep in Huntsville, Alabama, where he spent part of his time at the University of Alabama. Galama and Groot did not want to make a decision on their own; the whole question was too sensitive. On the other hand, time was of the essence. The longer they waited, the smaller the chance of finding an afterglow. A quick decision was made; they would wake up van Paradijs. Galama, meanwhile, contacted Richard Strom of the Westerbork Synthesis Radio Telescope to prepare for radio observations.

"The whole day was spent calling back and forth," says Groot. "It was a hectic time." Van Paradijs was in Huntsville, Groot and Galama were in Amsterdam, Costa was in Rome, and Heise and

The evolution of a gamma-ray burst is illustrated in this artist's conception. This phenomenon is the result of an exploding star, which sends gamma radiation into space and causes a spectacular explosion. To learn more about the history and future of GRB studies, visit *Astronomy.com* and click on the *Astronomy* magazine link. Jay Smith



This false-color Hubble image shows the visible fireball accompanying the gamma-ray burst GRB 970228, first discovered by Jan van Paradijs and his team. K. Sahu, M. Livio, L. Petro, D. Macchetto, STScI, and NASA



Since February 1997, the BeppoSAX satellite has continued to capture optical afterglows of gamma-ray bursts. This Hubble photo shows a dwindling afterglow (arrow) of a burst detected on December 11, 2001. The host galaxy can be seen as the faint smudge extending above and to the left of the afterglow position. D. W. Fox, J. S. Bloom, S. R. Kulkarni (Caltech), et al.

Piro were attending a conference in Tokyo along with Chryssa Kouveliotou, van Paradijs's wife and colleague, from the Marshall Space Flight Center in Huntsville. Each one had to talk with the other one — and meanwhile the clock was ticking. Piro remembers vividly how exciting it was in Tokyo. Earlier that day, at about 11:00 Universal Time (only eight hours after the gamma-ray burst), when the x-ray telescopes of BeppoSAX had already been observing the burst position for four hours, a bright x-ray source was indeed discovered on the edge of the error box of the Wide Field Cameras. "Right before I was to give my talk in Tokyo, Marco Feroci in Rome sent me the x-ray image," says Piro. The news could not have been hotter when he announced to his audience in Japan that BeppoSAX had chalked up a new first.

Costa was now under pressure. If the gamma-ray burst showed an x-ray afterglow, then chances were good that it would also be observable at radio wavelengths and visible light. He had already alerted his collaborator, Dale Frail of the National Radio Astronomy Observatory in the United States, who would be observing with the Very Large Array in New Mexico at wavelengths of 6 and 20 centimeters. But the radio telescope in Westerbork could also pick up radiation with a wavelength of 36 centimeters, and of course, the more observations that were done, the greater the chance of success. A quick decision had to be made. In the Netherlands it was already evening, and the constellation Orion would dip beneath the horizon in a couple of hours. If Westerbork didn't get going immediately, the opportunity would not present itself again until Saturday afternoon.

After soul-searching discussions with his colleagues in Rome and Tokyo, Costa came to a decision. Van Paradijs was given the exact position in the sky so that observations with the Westerbork telescope could be made that night. Van Paradijs called Galama, who had already gone home, and Galama contacted Westerbork. Before long, the 14 dish antennae of the WSRT turned toward the west, and so began the second search for a radio afterglow.

Abridged chapter from the book entitled *Flash! The Hunt for the Biggest Explosions in the Universe* by Govert Schilling. Copyright © 2002 by Cambridge University Press. Printed by permission.

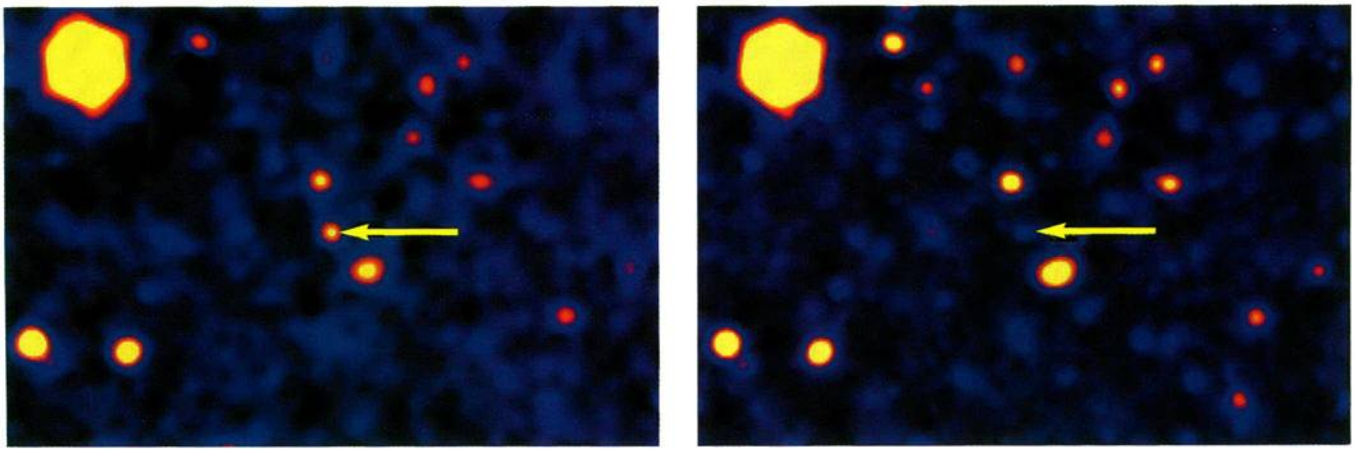
Of course, Galama was wildly enthusiastic. Maybe the Westerbork observations would lead to the first definite identification of a gamma-ray burst. It isn't often that a doctoral thesis comes up with such revolutionary results. He called Groot to tell him the good news. Groot was still at the institute analyzing the optical observations from the burst on January 11th. "I told Paul that we had the burst position and Westerbork was already working on it," says Galama. "Paul realized that on the same night we also had observing time on the William Herschel Telescope." On La Palma, John Telting would be taking photographs, for the second time, of the position of GRB 970111 in the constellation of the Serpent. Serpens was visible the entire night but Orion was about to sink below the horizon. Could Telting first take a photo of the position of GRB 970228?

It seemed to be the obvious thing to do but of course, there were many loose ends to tie up. Observation time on the WHT was granted on the basis of the proposal that was to look only at GRB 970111. Moreover, Costa had given the burst position to van Paradijs to be used for radio observations with the Westerbork array, not for observations with an optical telescope.

What now? In just over an hour it would no longer be possible to observe that part of the sky from La Palma, which meant that everything had to be handled with the utmost speed. Galama and Groot called van Paradijs again in Huntsville, but he couldn't be reached. They could leave a message on his answering machine but that would mean they would have to wait, which could well take a long time. Maybe they should go ahead and let the pictures be made and take care of the political fallout later. And so it was.

Groot called Telting, who aimed the 4.2-meter telescope, the largest optical telescope in Europe, at a low point, just above the western horizon halfway between the bright stars Aldebaran and Bellatrix; two images were made. It was now 23:48 Universal Time — less than 21 hours after the actual gamma-ray burst.

After taking a catnap, Groot and Galama immersed themselves the following morning in studying the pictures that had come to Amsterdam via the Internet. The William Herschel Telescope has a field of view of about 7 arcminutes, some-



These images of the GRB 971214 field, obtained with the 10-meter W. M. Keck Telescope on Mauna Kea, demonstrate the fading of an optical afterglow. The image on the left was taken about two days after the burst, while the image on the right was obtained about two months later and reveals a faint galaxy in the afterglow position (arrow).

S. G. Djorgovski and S. R. Kulkarni / W. M. Keck Observatory

what less than a quarter of the apparent diameter of the full Moon. The error box from the Wide Field Cameras on BeppoSAX was a bit smaller (6 arcminutes), but in that little area thousands of stars were visible. One of them could be the optical afterglow they were seeking, but how would they find it?

There was only one thing to do: Another picture had to be taken with the William Herschel Telescope so that they could search for that little point of light that had become fainter in the interim. This new photo should be taken, preferably, on Saturday night. Bad luck! La Palma was under heavy cloud cover. On the nights that followed, the skies remained cloudy. It would take time before anything could be known for certain.

A week passed but finally, on the evening of Saturday March 8, new photographs were taken at La Palma by Max Pettini from the Institute of Astronomy in Cambridge. To the human eye there was again a sweeping collection of thousands of faint light points, but a computer comparison with the photos from February 28 quickly showed that indeed, one puny little star had disappeared from the stage — a tiny point of light of magnitude 21.3, about one million times fainter than the faintest star that can be seen with the naked eye.

In the photo taken on February 28, the light source was clearly visible, almost on the edge of the error box of the Wide Field Cameras of BeppoSAX, right next to an even fainter dwarf star. In the pictures taken on March 8, the dwarf star could still be seen but there was no trace of the other object. Furthermore, the position neatly coincided with the x-ray source that had been photographed by one of the x-ray telescopes of BeppoSAX.

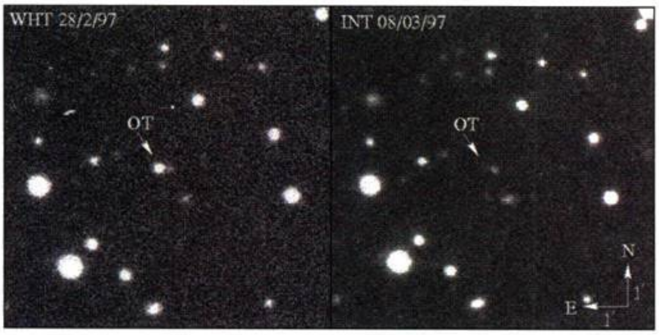
The first optical identification of a gamma-ray burst was now a fact. Apparently, the bursts are visible with an ordinary telescope if an observer is fast enough to catch it. But every minute counts, and after a few days there is no point in looking. Thanks to Enrico Costa's Gamma Ray Burst Monitor, John Heise's Wide Field Cameras, Jean in 't Zand's software, and the quick action of Paul Groot and Titus Galama, the position of a gamma-ray burst could finally be known to within a fraction of an arcsecond. Now big optical telescopes could be mobilized to search for the source of a gamma-ray burst. Perhaps in the place where that little flash of light faded into nothingness, there was a very faint neutron star, or a very far away galaxy.

A brilliant outcome, but Costa was seething. The Dutch had pulled off a first, in what he thought to be a reprehensible manner; van Paradijs had only been given the burst position to be used specifically and solely with the Westerbork telescope for radio observations. And now his team was publishing one IAU circular after another, which made it seem to all the world that he had all the strings in his hands. Nor was this just about the pictures from the William Herschel Telescope. In photos taken of the burst position with the 3.5-meter New Technology Telescope (NTT) at the European Southern Observatory in Chile, a very faint, stretched-out smudge of light was visible exactly at the point where the optical afterglow had been spotted. The nebular patch was almost certainly a distant galaxy. And although there could naturally be speculation about a chance superposition, it began to seem more and more convincing that the gamma-ray burst seen on February 28 had taken place at a distance of many billions of light-years.

"Jan was a tough one," says Costa. "He was extremely correct and he would never lie, but he was tough. He refused, for example, to synchronize the publication of our *Nature* articles, with the result that the *Nature* article about the optical afterglow appeared before our article about the x-ray afterglow, even though the x-ray one was discovered first."

The article by van Paradijs and his colleagues was published on April 17, 1997, just seven weeks after the gamma ray burst, and five weeks after the discovery of the faint galaxy. Van Paradijs had contacted the *Nature* editors on March 9th, directly after the identification of the optical afterglow. In the week after the NTT pictures were taken, the article was written post-haste. To speed things up, *Nature* asked the reviewing referees to react within 24 hours. Never before had so little time expired between a scientific discovery and its publication in *Nature*.

"We could never manage that," says Costa emphatically. "I am more of a hardware man; Jan was a much better astrophysicist. My poor English probably has something to do with it, too. The referees found my article very interesting, but it had to be fundamentally rewritten. That caused a delay of a month." Costa wanted the two articles to appear in the same issue of *Nature*, but van Paradijs wouldn't hear of it. "Take it up with the editors," was his reaction. The *Nature* editors in turn told Costa that it really was a question between him and van Paradijs. The article about the x-ray afterglow of GRB 970228 appeared on June 19, a good two months after the van Paradijs publication.



These photos of the area where GRB 970228 were recorded show the fading optical afterglow, or optical transient (OT), of the gamma-ray burst over time. The photo on the left was taken on February 28, 1997, with the William Herschel Telescope shortly after the gamma-ray burst was discovered; the photo on the right was taken on August 3, 1997, with the 2.5-meter Isaac Newton Telescope. Jan van Paradijs et al./Max Pettini

Although it would take until the middle of May before there was compelling confirmation of the cosmological distance scale of gamma-ray bursts, the discovery of the optical afterglow of GRB 970228 is generally regarded as the biggest breakthrough in the research so far. The revolutionary observations were the subject of the day during the 4th Huntsville Gamma Ray Burst Symposium in October of that year, and *Science* magazine listed it among the ten most important scientific breakthroughs of 1997. Together with the BeppoSAX team, van Paradijs received the 1998 Bruno Rossi prize from the American Astronomical Society, and in 1999 in his own country he was awarded the physics prize from the Dutch Physical Society.

Ed van den Heuvel, director of the Astronomical Institute "Anton Pannekoek" at the University of Amsterdam, says it was no coincidence that van Paradijs and his group succeeded in making the long-awaited breakthrough. "Jan often said that life is a question of priorities. He had a nose for scientific problems that were not only interesting but also held the promise of yielding important results."

After the success surrounding the February burst, van Paradijs and his group wanted, in the next few months, to set up a worldwide network that would be able to track down afterglows even more quickly in the future. He succeeded in getting many small and medium-sized telescopes to agree to "override proposals," which meant that proposals from his team had the right to break into an ongoing observational program and take over the telescope if there was a new gamma-ray burst to study. He supplied his graduate students with pagers and mobile phones. In the meantime, he was busy in Amsterdam and Huntsville, firing up the interest and enthusiasm of students for the most hectic domain in all of astronomy.

For Paul Groot the atmosphere was too hurried and chaotic. A year after the February burst, he turned back to his original Ph.D. research on certain types of variable stars: "a great subject, full of good physics." But for Titus Galama and his new colleague, Paul Vreeswijk, this excitement was their cup of tea. They worked far into the night, slept with their cell phones under their pillows, and were never without telephone numbers of telescopes all over the world. After all, you never can tell.

In 1998 Jan van Paradijs was diagnosed with cancer. In a hospital in Huntsville he received chemotherapy, but to no avail. In the summer of 1999, weakened by the onslaught of his sickness, he flew to Amsterdam, accompanied by his wife, to enter the Free University hospital for the most advanced therapy. Between treatments, he kept up with the literature, discussed research problems with his graduate students, and worked with Chryssa on a comprehensive article on gamma-ray bursts.

On October 22, during the 5th Huntsville Gamma Ray Burst Symposium, *Science* published his last article that he was to see in print, on the relationship between gamma-ray bursts and supernovae. By then it was clear that he had not much longer to live. He didn't make it to the cum laude graduations of Paul Groot and Titus Galama on the 7th and 8th of December.

Jan van Paradijs died on November 2, 1999, at the age of 53, less than a thousand days after that February burst that propelled him to world fame. ■

Govert Schilling is a science writer and astronomy publicist living in the Netherlands. He is a frequent contributor to Astronomy *and has written more than twenty books on the subject.*

The Legacy of Jan van Paradijs (1946-1999)

The name of Jan van Paradijs will forever be associated with the revolutionary breakthrough that propelled the study of gamma-ray astronomy forward and solved one of its greatest mysteries – the riddle of the distance scale of gamma-ray bursts. "This could be a turning point in GRB astronomy," wrote van Paradijs and his colleagues in their *Nature* article of April 17, 1997, shortly after their discovery in February 1997. "A more profound understatement would be hard to think of," notes Govert Schilling.

Photo courtesy of NASA

But van Paradijs's 30-year career as a high-energy astrophysicist was marked by much more than a single discovery. After earning his undergraduate and doctoral degrees from the University of Amsterdam, he became a faculty member and research scientist at the university in 1970, remaining there nearly his entire career. In 1993, he became the Pei-Ling Chan eminent scholar in astrophysics at the University of Alabama at Huntsville, which became his second home. He published more than 300 scientific papers and edited more than eight books throughout his career. In addition, he worked with the Burst and Transient Source Experiment team (BATSE), which monitored nearly the entire sky for gamma rays with the Compton Gamma Ray Observatory. He also served on the boards of directors of the Netherlands Foundation for Research in Astronomy and the European Astrophysics Doctoral Network.

"Jan was one of the most knowledgeable, productive, and wide-ranging workers in our field, a master of both observational and theoretical high-energy astrophysics," says BATSE principal investigator Jerry Fishman. "He was at or near the top of everyone's list of the world's greatest astrophysicists." – *Elesa Janke*

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sky Show

February 2003

Jupiter parades across center stage.

by Martin Ratcliffe and Alister Ling

Saturn may be the most beautiful planet, but only Jupiter can truly rule the night. On February 2, the giant planet lines up with Earth and the Sun, rising at sunset and setting at sunrise. Because it lies opposite the Sun in our sky, astronomers call this event "opposition."

This is a great time to become familiar with its systems of clouds. Jupiter rotates once every 9 hours and 55 minutes, so fast that it noticeably bulges at the equator and appears flattened at the poles. Even in small telescopes, the four Galilean moons present an ever-changing arrangement of diamonds on this king's crown — or belt, more accurately, because the moons orbit Jupiter's equatorial regions.

This is a good time to observe Jupiter because Earth lies in the plane of the moons' orbits, producing mutual occultations and eclipses. A moon can pass in front of another or cast its shadow onto another and make it fade. One of the best events is well timed for Europe and the Americas on February 10.

Saturn now lies high in the southeast as darkness falls. Remember that if the air is a bit hazy it usually implies a stable atmosphere, so it's well worth aiming your scope at the planets even when conditions are not good for deep-sky objects.

The full glory of the winter sky greets the eye in the east. It's no coincidence that the brightest stars congregate here, for this is where many stellar nurseries reside, including the marvelous Orion Nebula (M42). Massive stars begin their lives in such cocoons and burn most brightly. Scan this region with binoculars to see one marvel after another.

Experts correctly claim that binoculars should be prized more than they are, as far as equipment goes. You can't otherwise magnify a large patch of sky with two eyes open. A magnificent array of stars, mostly unnoticed in a telescope, enshrouds the bright star Alpha (α) Persei. The wide field also lets you eavesdrop on an eclipsing binary, where a fainter star blots out much of the light of a brighter one. In the case of RZ Cassiopeiae, you can observe a brightness change in less than 15 minutes.

As dawn breaks in the frosty morning, brilliant Venus catches the eye in the southeast. During the first week of February, a lone "star" closer to the horizon turns out to be Mercury, the innermost planet of the solar system. To the upper right of Venus, two ruddy objects flicker together. They are the planet Ares, better known as Mars, and the star Antares. Watch Antares climb away from Mars with each passing morning. The Red Planet follows Venus in its eastward journey. Make sure you have an eye out on January 28 and on February 26 and 27, when the crescent Moon passes Venus.

Telescopically, Venus fills out from a 60 percent phase to 70 percent because it is scooting around the far side of the Sun from our perspective. This also means that it shrinks in size. Mars, located in the distant background, shows a tiny 6"-diameter disk that will frustrate all but the most patient planetary observers.

Jupiter appears bigger and brighter than at any other time this year, providing backyard observers with excellent views of its intricate cloud belts. NASA/JPL/University of Arizona

2003 February

1 New Moon is at 5:48 A.M. EST

2 Jupiter is at opposition, 4 A.M. EST (page 63)

3 Mercury is at greatest western elongation (25°), 8 P.M. EST

7 The Moon is at apogee (251,377 miles from Earth), 4:58 P.M. EST

9 First Quarter Moon is at 6:11 A.M. EST

11 The Moon passes 3° north of Saturn, 10 P.M. EST

15 The Moon passes 4° north of Jupiter, 1 P.M. EST

16 Full Moon is at 6:51 P.M. EST

17 Uranus is in conjunction with the Sun, 5 P.M. EST

19 The Moon is at perigee (226,704 miles from Earth), 11:15 A.M. EST

20 Mercury passes 1.6° south of Neptune, 7 P.M. EST

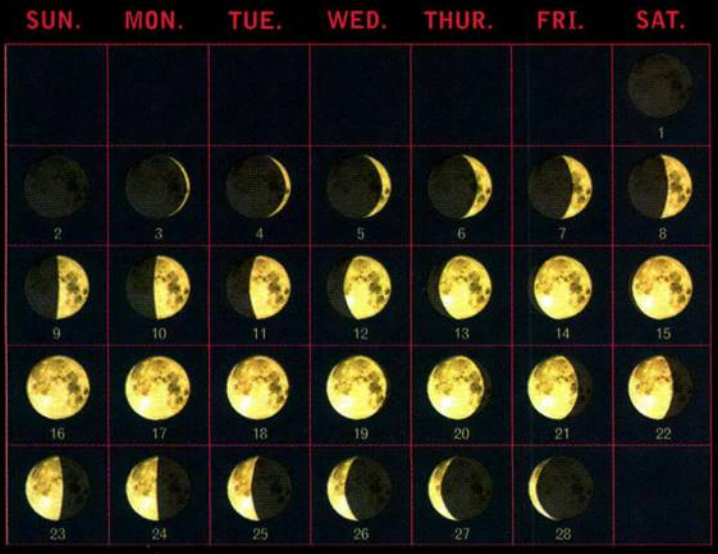
22 Saturn is stationary, 5 A.M. EST

23 Last Quarter Moon is at 11:46 A.M. EST

24 The Moon passes 1.9° south of Mars, midnight EST

27 The Moon passes 5° south of Venus, 6 A.M. EST

28 The Moon passes 5° south of Neptune, 10 A.M. EST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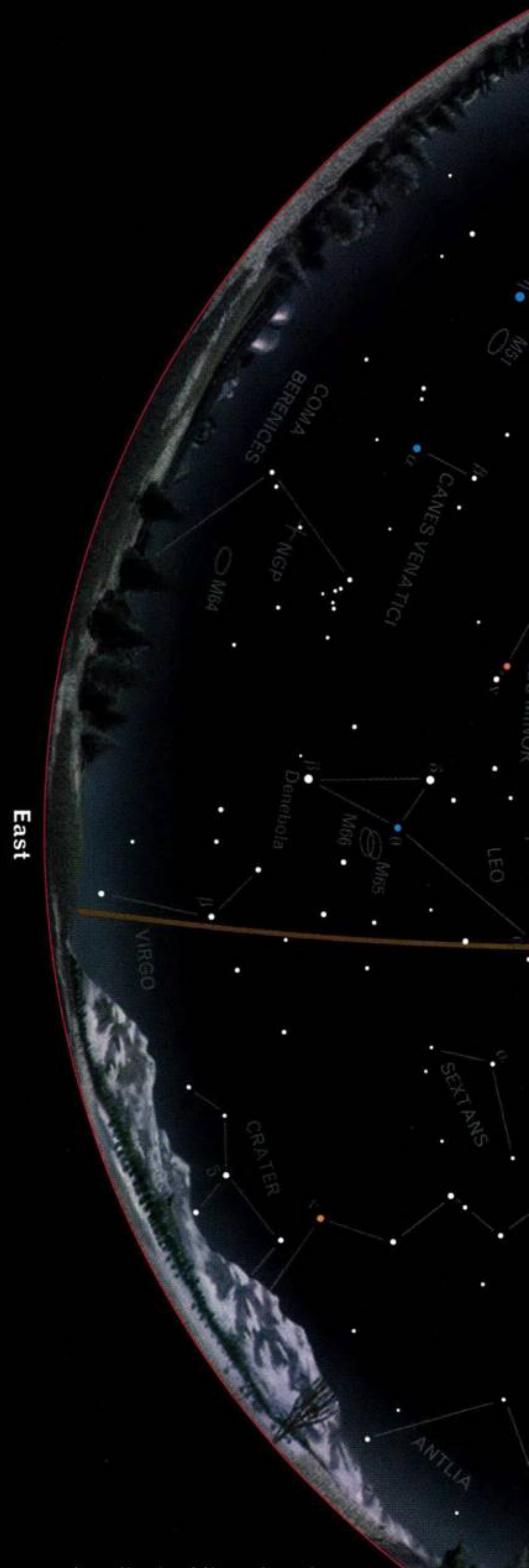
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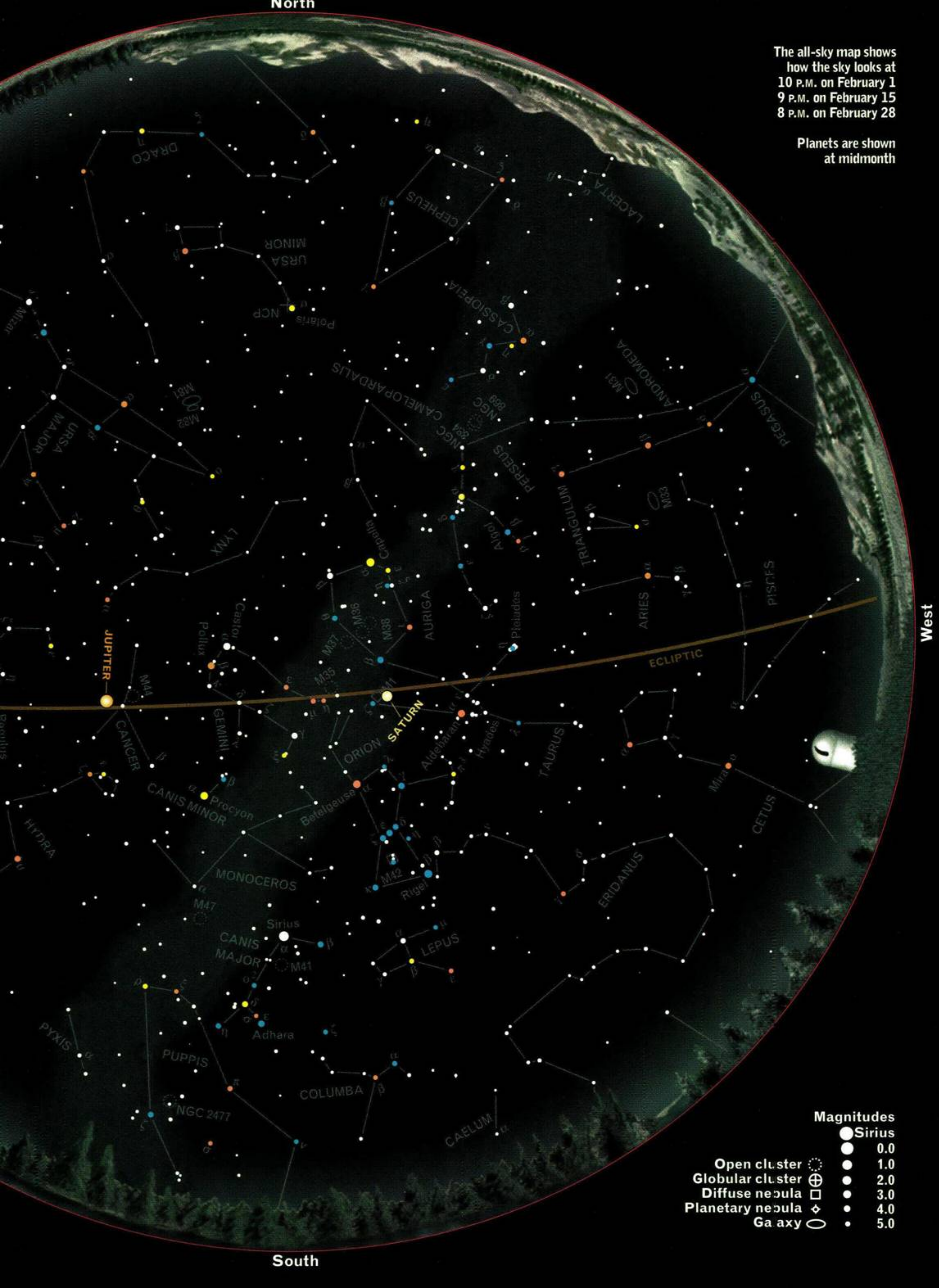
This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.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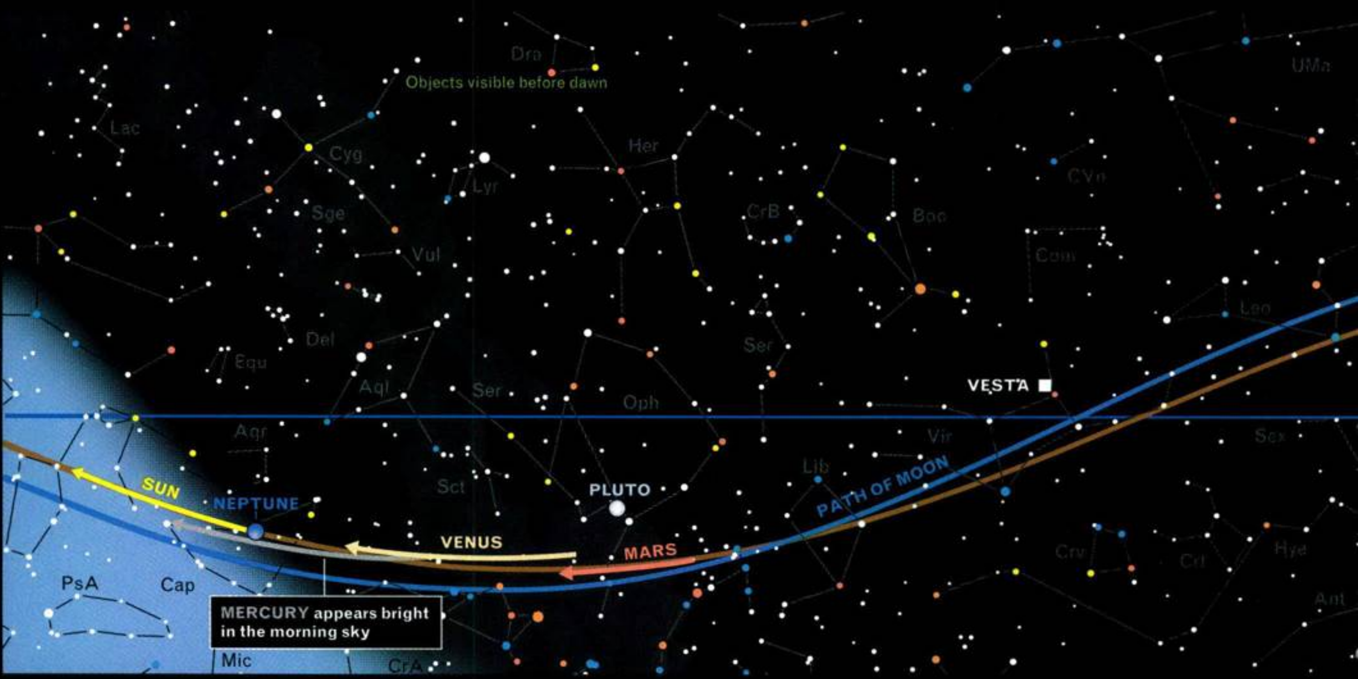
Polaris
NCP
CASSIOPEIA
Mizar
ANDROMEDA
M31
CAMELOPARDALIS
M81
M82
URSA MAJOR
NGC 869
NGC 884
PEGASUS
PERSEUS
TRIANGULUM
M33
LYNX
Capella
Algol
AURIGA
M36
M38
M37
ARIES
PISCES
Pleiades
Castor
Pollux
JUPITER
M44
M35
M1
ECLIPTIC
GEMINI
SATURN
Aldebaran
Hyades
TAURUS
CANCER
ORION
CANIS MINOR
Procyon
Betelgeuse
Mira
CETUS
HYDRA
MONOCEROS
M42
Rigel
ERIDANUS
M47
Sirius
CANIS MAJOR
M41
LEPUS
Adhara
PYXIS
PUPPIS
COLUMBA
NGC 2477
CAELUM
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
10 P.M. on February 1
9 P.M. on February 15
8 P.M. on February 28

Planets are shown
at midmonth

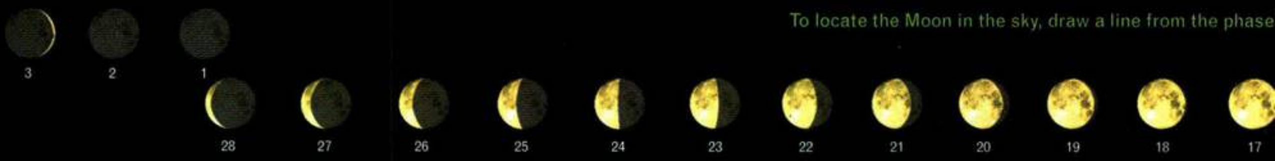
Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objec

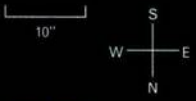

Dra
Objects visible before dawn
Lac
Cyg
Lyr
Her
Sge
Vul
CrB
Boo
Com
CVn
UMa
Leo
Del
Equ
Aql
Ser
Ser
Oph
VESTA
Aqr
Vir
Sex
SUN
NEPTUNE
Sct
PLUTO
Lib
PATH OF MOON
VENUS
MARS
Crv
Crt
Hya
PsA
Cap
Ant
Mic
CrA

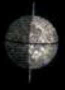
MERCURY appears bright in the morning sky

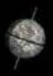
To locate the Moon in the sky, draw a line from the phase

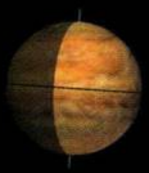

3
2
1
28
27
26
25
24
23
22
21
20
19
18
17

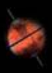
PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITE
Date	February 1	February 28	February 15	February 15	February
Magnitude	0.0	−0.3	−4.2	1.1	−2.6
Angular Size	7.1"	5.2"	17.8"	5.7"	45.3"
Illumination	56%	88%	66%	91%	100%
Distance (AU) from Earth	0.942	1.293	0.936	1.656	4.355
Distance (AU) from Sun	0.421	0.456	0.722	1.568	5.317
Right Ascension (2000.0)	19h11.2m	21h38.9m	18h50.9m	17h10.1m	8h56.5m
Declination (2000.0)	−21°06'	−16°09'	−21°01'	−22°45'	18°12'





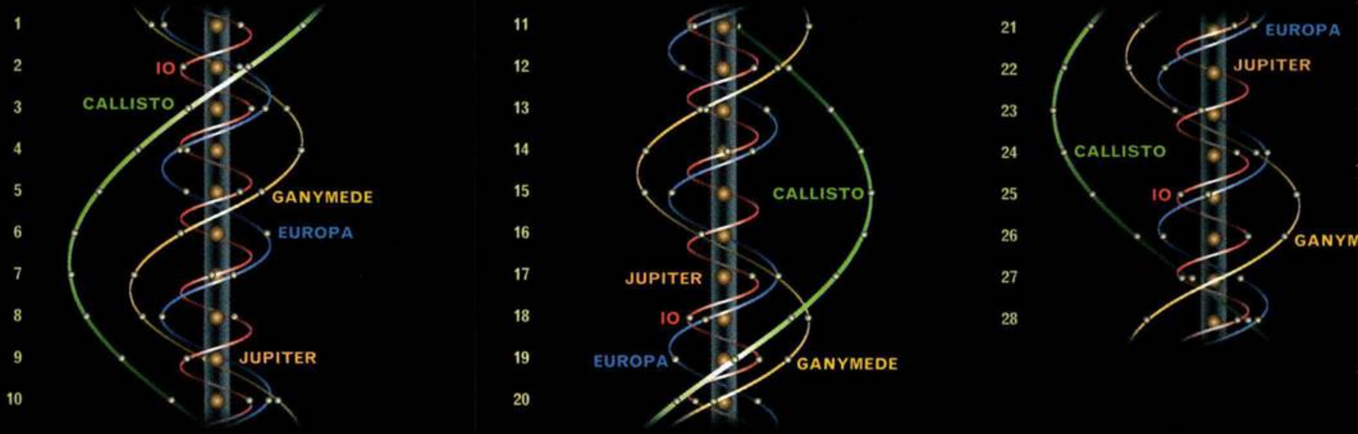




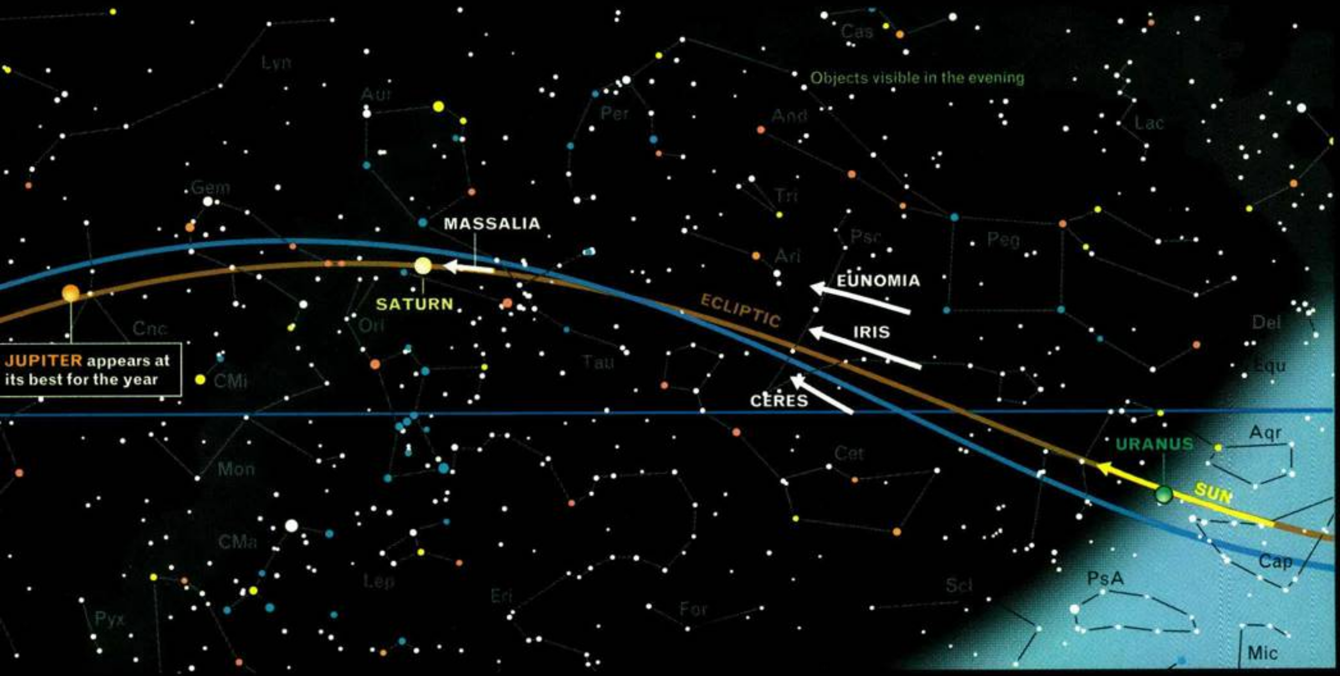


Jupiter's Moons

Dots display positions of Galilean satellites at 11 P.M. EST on date shown. South is at top to match the view in a telescope.

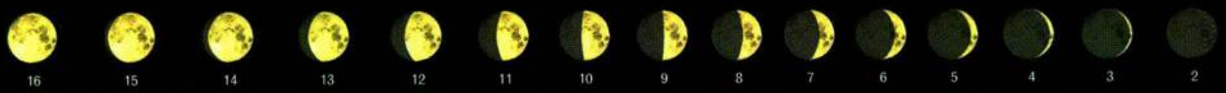


uring the month.


Lyn
Cas
Aur
Per
Objects visible in the evening
And
Lac
Gem
Tri
MASSALIA
Psc
Peg
Ari
EUNOMIA
SATURN
ECLIPTIC
Cnc
Ori
IRIS
Del
CMi
Tau
Equ
CERES
Aqr
URANUS
SUN
Mon
Cet
CMa
Cap
Lep
Eri
For
Scl
PsA
Pyx
Mic

JUPITER appears at its best for the year

own for the day straight up to the curved light-blue line.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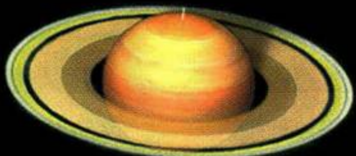
5
4
3
2

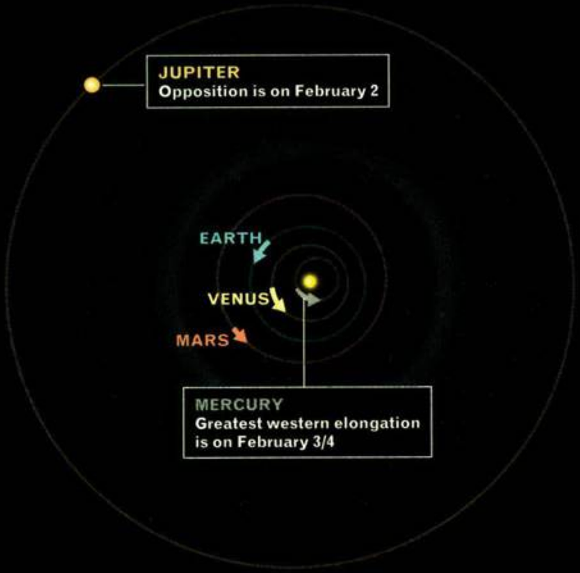


SATURN	URANUS	NEPTUNE	PLUTO
February 15	February 15	February 15	February 15
−0.1	5.9	8.0	13.9
19.4″	3.4″	2.2″	0.1″
100%	100%	100%	100%
8.553	21.004	31.038	30.991
9.033	20.018	30.083	30.612
5h26.1m	22h04.0m	20h54.6m	17h17.5m
22°04′	−12°37′	−17°23′	−13°46′

The Planets in Their Orbits

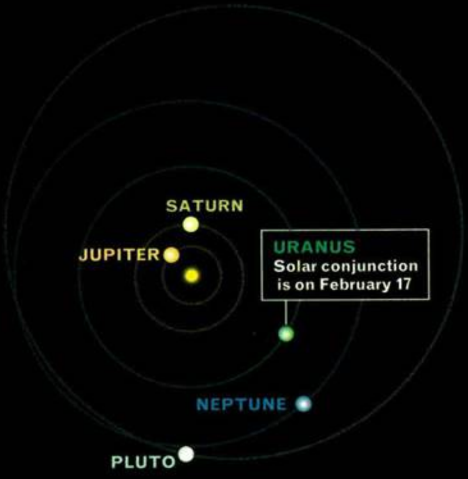
Arrows and dots show planets' positions during the month.

DE


EARTH
VENUS
MARS

JUPITER
Opposition is on February 2

MERCURY
Greatest western elongation is on February 3/4


SATURN
JUPITER
NEPTUNE
PLUTO

URANUS
Solar conjunction is on February 17

Sparkling Diamond Dust

Like a clutch of diamonds, the Alpha (α) Persei moving cluster catches one's breath. A simple pair of binoculars is all you need to see these glittering jewels from your backyard. This delightful group has often been overlooked because a telescope with its higher magnification sees right through it.

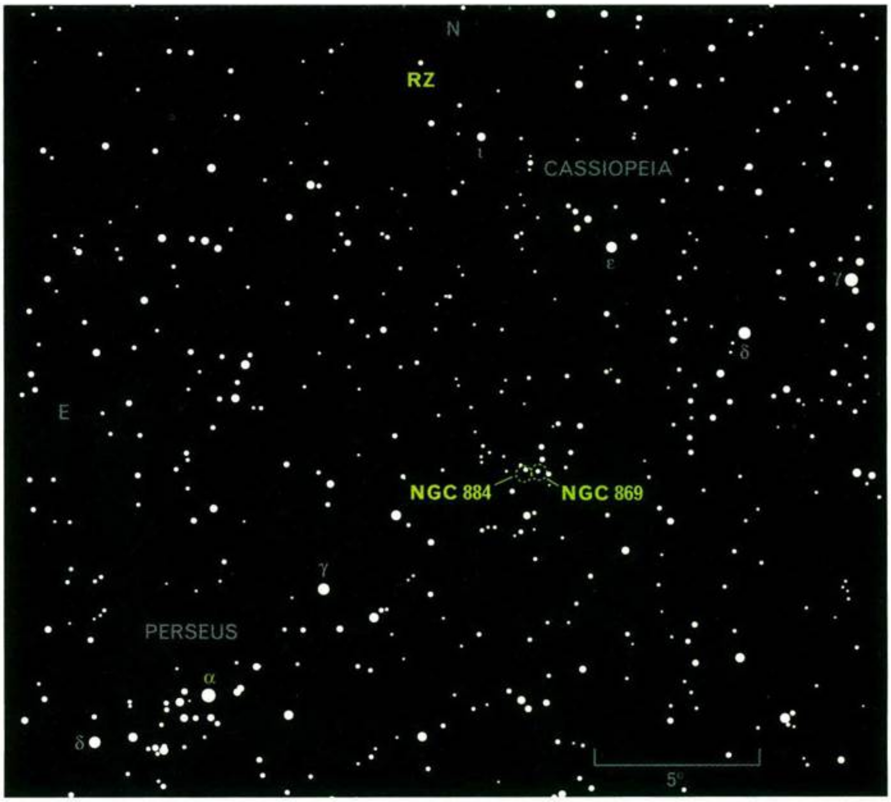
The grouping of these bright stars is no coincidence. They were all born from the same large cloud of gas and dust, pressured together by the various forces in the Perseus arm of our galaxy. The massive stars burn the brightest, and their spectral types, O and B, reflect their name, an OB association. This one lies roughly 600 light-years from Earth.

The shape of the cluster brings to my mind a dragon lying down, with the brightest star, Mirfak (Alpha Per), as its eye set in a proudly raised head. A noticeably yellow-orange star sits where the tail lifts up.

The tangle of stars encompassing the great Double Cluster (NGCs 869 and 884) is another OB association. Although much more distant, some 7,500 light-years away, it still stands out well from the background of fainter stars.

The next time you observe under dark country skies, leave the telescope idle for a few minutes and scan these rich fields with binoculars. Let yourself get lost in the starfields of the Milky Way.

The matched set of star clusters in Perseus known as the Double Cluster offers small-scope owners one of the finest sights in the autumn or winter sky. Jason Ware

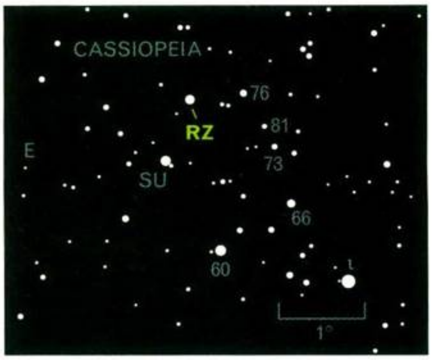


Surprising Eclipses

It's fun to watch a sky that changes every 10 minutes, especially when nobody knows exactly what's going to happen. RZ Cassiopeiae is like a clock that chimes differently every time it comes around. Every 28 hours and 41 minutes, a fainter star moves in front of a brighter one, hiding some of the latter's light. Unlike its more famous eclipsing binary brother, the demon star Algol in Perseus, this pair mixes in individual variability, so when you least expect it, RZ Cas will stall, then rise or fade faster than usual.

RZ Cas reaches minimum light at midnight EST on February 1/2, 11:30 P.M. on February 7, 11 P.M. on the 13th, 10:30 P.M. on the 19th, and 10 P.M. on the 25th. You can add 1 day, 4 hours, and 41 minutes until you find a time more suitable for your location.

To find RZ Cas, look for the "W" of Cassiopeia standing on its side like an "E" in the northwest. Go in a straight line from the upper left to the upper right star (from Delta [δ] to Epsilon [ε] Cas), then continue an equal distance to the northeast. The brighter star here is Iota (ι) Cas. Check it out on a regular night so you become familiar with the normal view.



About 2.5 hours before mideclipse, RZ Cas will be brighter than the 6.6-magnitude star (decimals have been omitted to avoid confusion with stars). Check every 20 minutes, until 30 minutes before the midpoint. Compare RZ with the trio of fainter stars every 10 minutes as it goes through minimum. If you find this type of observing fun, check out the American Association of Variable Star Observers' web page — www.aavso.org — for other ideas.

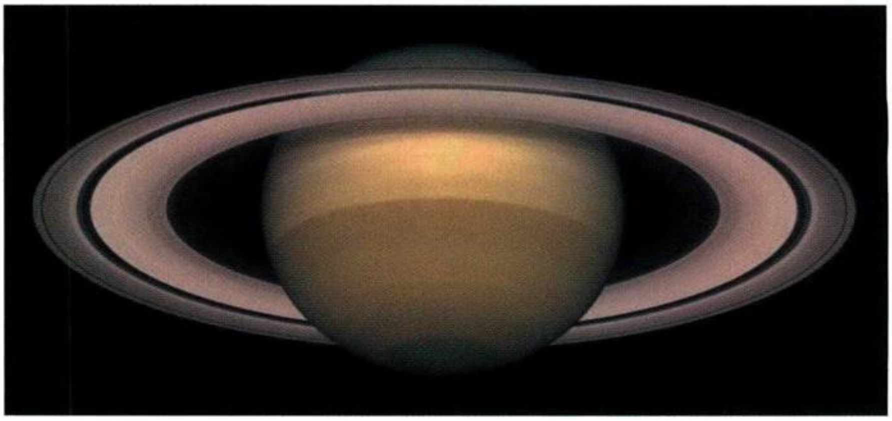
sky Show

▶ Jupiter and Saturn continue their spectacular appearance during the cold winter nights. With the exception of the Moon, Jupiter ranks as the brightest object in the night sky until Venus rises in the early morning hours. Saturn is no slouch either, a conspicuous point of light high in the east as soon as the sky starts to darken. Jupiter reaches a decent altitude within an hour after sunset.

Let's begin with **Saturn**. By 8 P.M. local time, Saturn appears nearly overhead and glows at magnitude –0.1, brighter than any other object in the region. It lies among the stars at the eastern end of Taurus the Bull, east of the Pleiades and Hyades star clusters. On February 10, a slightly gibbous Moon stands above the Hyades, with Saturn to their east. By February 11, Saturn sits about five moon-widths below the waxing Moon. The next night sees the Moon crossing into Gemini, near the fine open star cluster, M35, with Saturn to its west.

Saturn's ring system is the best telescopic sight of the winter sky. This year we see the broadest possible view of the rings' southern face. Because Saturn's axis tilts 26.7° to the plane of its orbit around the Sun, our perspective on the rings changes constantly. Throughout Saturn's 29.5-year orbital period, we see alternately the rings' southern face, an edge-on view, their northern face, and an edge-on view again. Next year Saturn's rings will begin closing, and by 2009 they will appear edge-on.

Most telescopes will show the three principal rings: the outer A ring, the bright B ring, and the inner C ring. A dark gap called the Cassini Division separates the A and B rings. Saturn retains a family of more than 30 moons, a number that's been growing in recent years. The brightest is Titan, an easy-to-spot, 8th-magnitude object that orbits Saturn every 16 days. Iapetus rates as the most unusual moon. In mid-February it appears at its brightest, lying on the western side of Saturn. Iapetus then shines at magnitude 10.1 because its brighter hemisphere faces us. When Iapetus lies at eastern elongation, it dims to magnitude 11.9 because much darker material covers the opposing hemisphere. The two-faced moon lies three times farther from Saturn than Titan and takes 80 days to orbit.



Look for the dark Cassini Division that separates Saturn's outer A ring from the brighter B ring, and the narrow Encke Gap near the outer edge of the A ring. NASA and the Hubble Heritage Team (STScI/AURA)

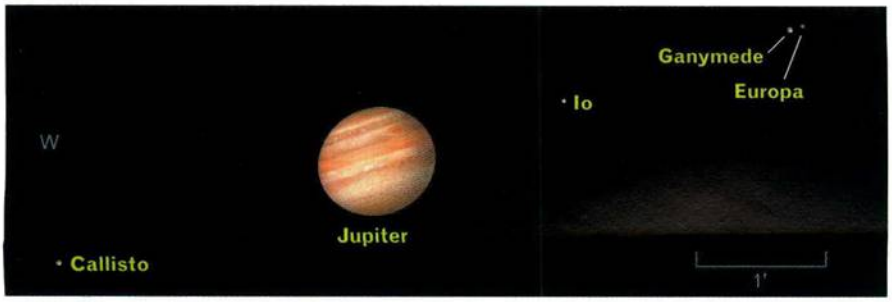
Jupiter rises just as the Sun sets during February, indicating that the solar system's largest planet has reached opposition. The planet lies in Cancer the Crab, just east of the Beehive Cluster (also known as Praesepe and M44), a fine open star cluster visible in binoculars from most locations and to the naked eye from dark sites. On February 2, the date of opposition, Jupiter stands about 30° above the eastern horizon at 8 P.M. local time. It's the brightest object in the evening sky, except when the Moon joins it, shining at magnitude –2.6. On February 15, the Moon is just one day away from its full phase. The brilliant orb rises within minutes of Jupiter, and 5° separate the two.

At opposition, Jupiter's globe spans 46" across its equator and 43" from pole to pole. This flattening can be seen in small telescopes and results from Jupiter's rapid, less than 10-hour, rotation period.

Telescopic viewers benefit from Jupiter's fast rotation. Spots and plumes in the jovian atmosphere move noticeably across the face of the planet within 15 to 20 minutes. When opposition occurs during the winter months, nights are long enough that a patient observer can view the entire globe of Jupiter as it rotates. All scopes will easily pick out the two dark equatorial belts. Patience at the eyepiece, and watching Jupiter carefully for some minutes, will reveal an alternating series of belts and zones and occasional dark rifts or loops intruding from the belts into the zones.

Equally attention-grabbing are the dynamic activities of Jupiter's four bright moons: Io, Europa, Ganymede, and Callisto. These moons orbit Jupiter in 1.8 days, 3.6 days, 7.2 days, and 16.8 days, respectively. Note the simple relationship between the periods of the first three moons, representing a 1:2:4 ratio. Such

Beginning around 9:05 P.M. EST (below) and lasting until nearly 10:45 P.M. on February 10, Europa will first pass in front of Ganymede and then eclipse it. *Astronomy*: Roen Kelly



orbital relationships reveal that the moons' orbits are tidally locked.

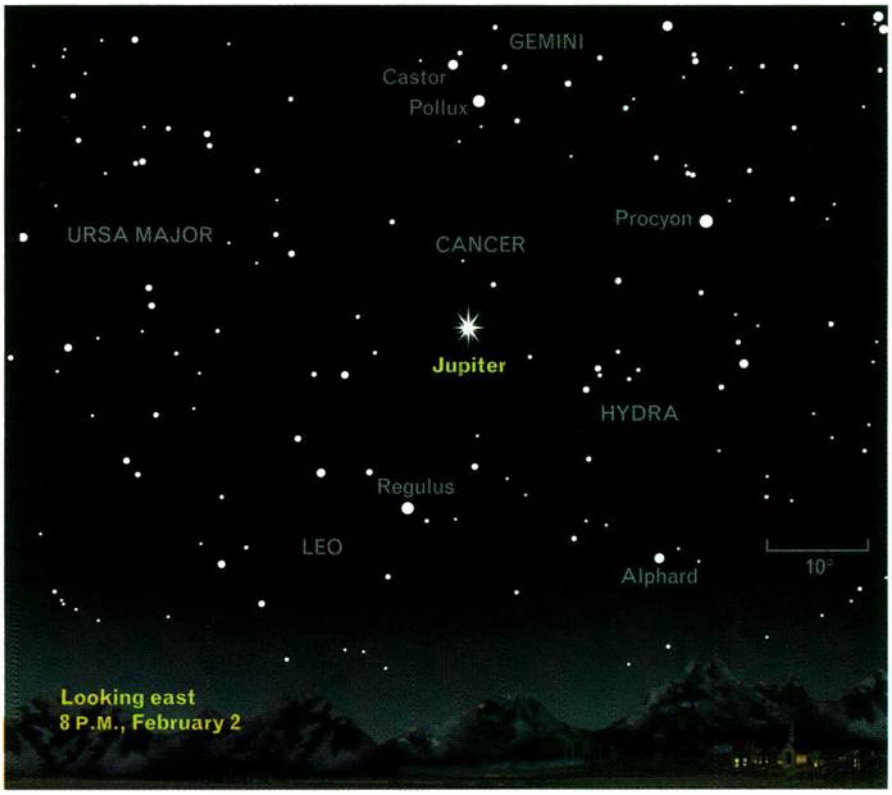
The relative positions of the satellites change from night to night — and sometimes hour to hour. This is a good year to watch the moons because, for the first time in six years, Earth lies in their orbital plane. Occasionally, one moon will pass in front of another and occult it from view, or a moon's shadow will fall on another, creating an eclipse and causing a drop in brightness. See "Shadow Play around Jupiter" (December 2002) for details on observing these rare events.

Accurate timings of these mutual events will help astronomers refine the orbits of Jupiter's moons. An active observing campaign is now underway. To access information on how you can participate, check the website of the International Occultation Timing Association at http://lunar-occultations.com.

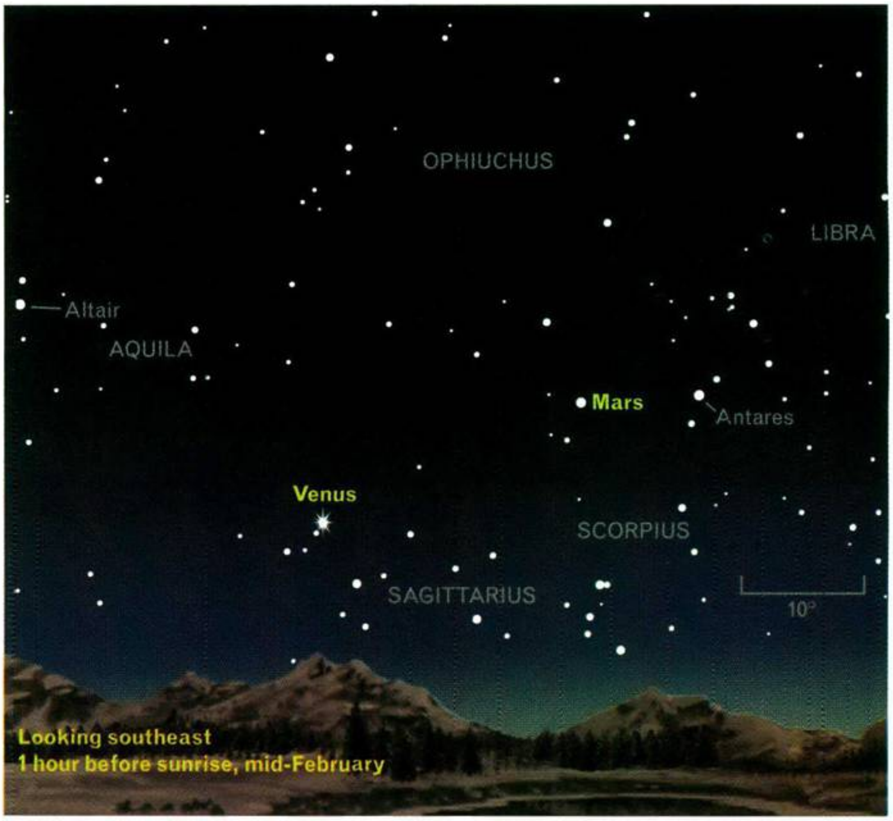
Mars rises around 3 A.M. in early February and stands 5° north of Antares, the brightest star in Scorpius the Scorpion. The telescopic view will generate little interest this month: At a distance of about 150 million miles, the planet displays an angular diameter of 6" — too small to show much detail. Observers remain excited about the record-breaking apparition of Mars coming this summer. Interest will rise when Mars reaches 10" across in mid-May.

An hour after Mars rises, **Venus** follows suit. Dazzling at magnitude –4.2, Venus crosses northern Sagittarius this month. A telescope will show Venus's phase waxing from 60 percent to 70 percent lit during February while its apparent size decreases correspondingly. Venus starts the month at 20" across and loses 4" by the 28th. A waning crescent Moon glides past Mars on February 25 and past Venus on the 27th.

Mercury makes a morning appearance during the first part of February, reaching greatest western elongation (25° from the Sun) on February 3. The inner planet grows brighter throughout the month, starting at magnitude 0.0 and ending at magnitude –0.3. On February 21, Mercury passes less than 2° south of Neptune, which is too faint to be seen. Soon thereafter, Mercury gets lost in the growing twilight before dawn.



Looking east
8 P.M., February 2



Looking southeast
1 hour before sunrise, mid-February

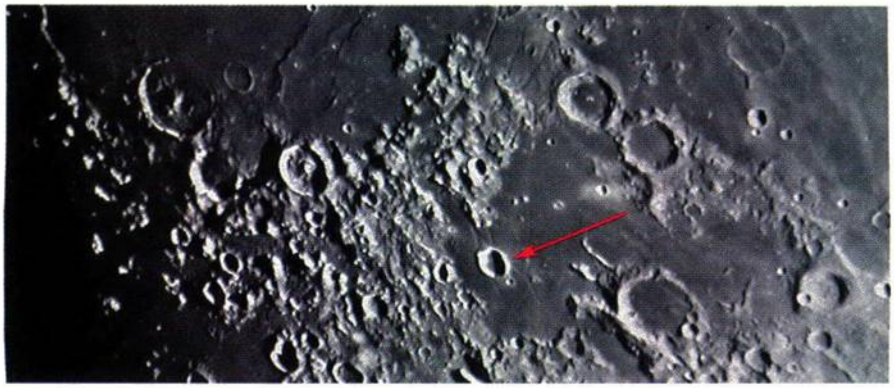
Meteors and Moons

▶ There are no significant meteor showers this month, and the rate of sporadic meteors is very low. However, keep a look out for the occasional fireball.

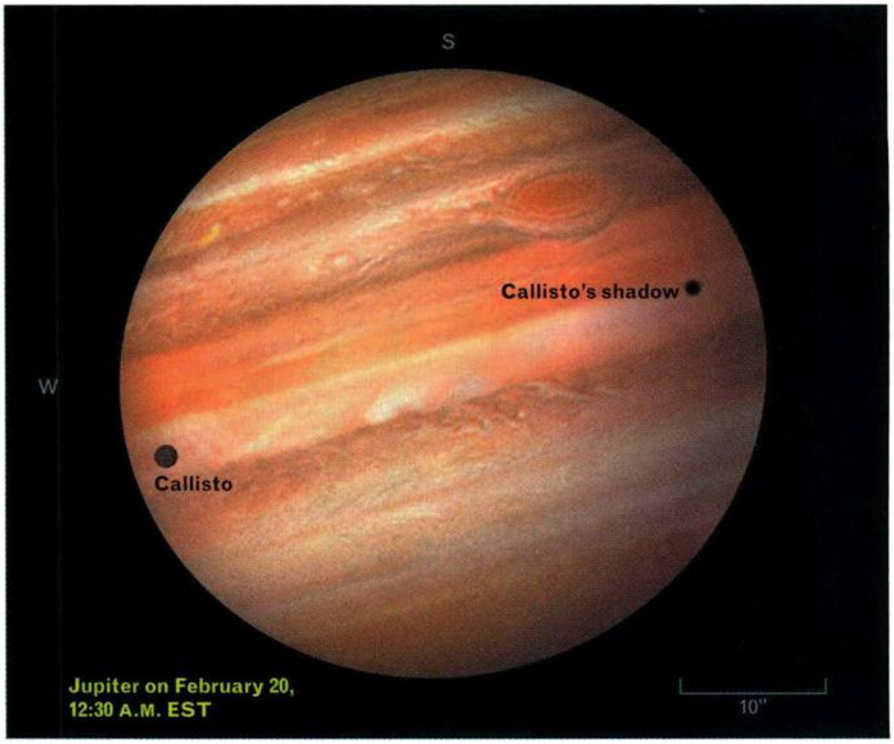
Ramsden Crater

This diminutive crater nestles between the giant crater Gassendi and the small lava-filled region known as Palus Epidemiarum that lies southeast of Mare Humorum. The 15-mile-wide crater is remarkable for the system of rilles that crisscrosses it. On its northern flank, the rille system forms the impression of a capital "N." Two more rilles intersect the walls of the crater to the south and southeast. If you catch the Sun's rays rising over this feature, you'll notice what appear to be breaks in the crater wall caused by the rilles. However, closeup photographs indicate that the rille system was already in place before the crater was formed, so the impression may be a false one.

The Palus Epidemiarum region is very smooth and stands in stark contrast to the region to its west, which reveals a jumbled terrain of mountains and craters. The N-shaped rille appears to connect to a short chain of mountains that runs to the shores of Mare Humorum. A twisting valley linked to Mare Humorum marks the western flank of the mountains. The valley floor is crossed by a rille that joins to a more complex system that borders the eastern shores of Mare Humorum.



The 15-mile-wide flooded crater Ramsden (arrow) and its surrounding network of rilles sits in Palus Epidemiarum, southeast of Mare Humorum. From the *Consolidated Lunar Atlas* (LPL/UA)



Jupiter on February 20, 12:30 A.M. EST

Jupiter's Satellites

The rare occultations, eclipses, and transits involving the outer Galilean moon, Callisto, continue. During each 12-year orbit of Jupiter around the Sun, only two series of Callisto events occur. The events listed in the table are given in Universal Time and Eastern Standard Time. Events that occur on either side of midnight are shown twice*, since the date changes for observers in Europe or the United States. Tr = transit; I = ingress; E = Egress; Oc = occultation; Sh = shadow transit; Ec = eclipse; D = disappearance; R= reappearance. The events are worth viewing due to their relative rarity.

Catch Callisto

	UT	EST	Events
Feb. 3	10:49	5:49 A.M.	IV.Tr.I.
	11:05	6:05 A.M.	IV.Sh.I.
	15:35	10:35 A.M.	IV.Oc.D.
	15:53	10:53 A.M.	IV.Sh.E.
Feb. 11	16:35	11:35 A.M.	IV.Oc.D.
	23:42	6:42 P.M.	IV.Ec.R.
Feb. 19		8:01 P.M.	IV.Tr.I.*
Feb. 20	1:01		IV.Tr.I.*
	5:04	12:04 A.M.	IV.Sh.I.
	5:47	12:47 A.M.	IV.Tr.E.
	9:53	4:53 A.M.	IV.Sh.E.
Feb. 28	6:56	1:56 A.M.	IV.Oc.D.
	11:47	6:47 A.M.	IV.Oc.R.
	12:51	7:51 A.M.	IV.Ec.D.
	17:44	12:44 P.M.	IV.Ec.R.

*** Events that occur on either side of midnight are shown twice.**

Comet C/2001 RX14 (LINEAR)

▶ Most comets come and go within a couple of months, and some show up with little advance notice. However, when their nearest point to the Sun, perihelion, lies outside Earth's orbit, their motion across our sky proves much more leisurely. That's the case with Comet C/2001 RX14 (LINEAR). On the inside track, Earth glides ahead of the comet, making it appear to head westward across the sky.

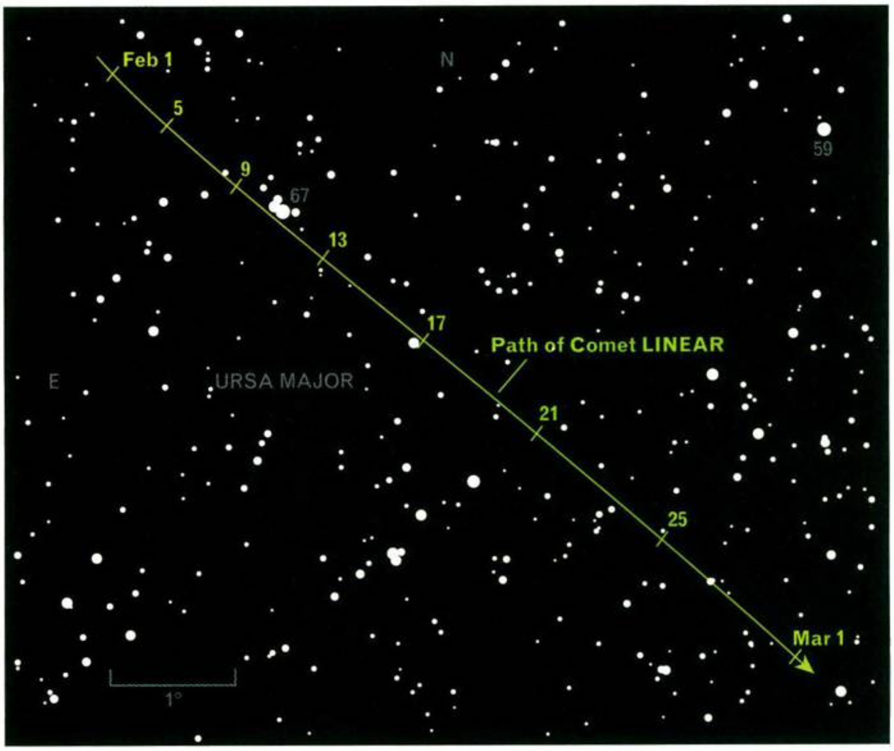
All *Astronomy* readers are familiar with the Big Dipper, but some might not be aware just how far south the constellation of Ursa Major the Great Bear actually extends. Skirting below one of the paws of the bear, RX14 (LINEAR) comes within reach of an 8-inch scope under decently dark, Moon-free skies. Experienced observers with smaller scopes should be able to detect its 10th-magnitude glow without difficulty.

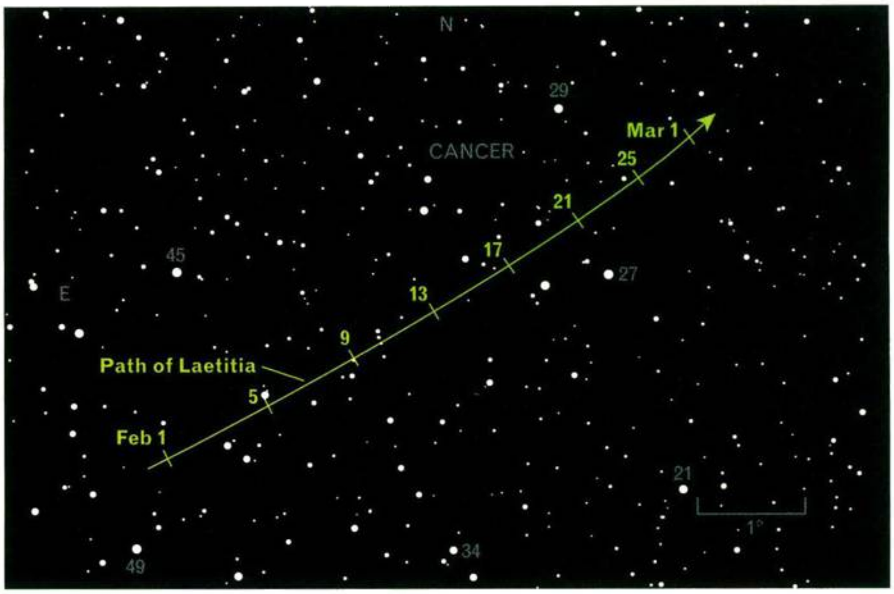
If you imagine a hole in the bottom left corner of the Dipper and some drops coming out of it, you'll be able to find the 5th-magnitude double star 67 Ursae Majoris. It is a wide, unequal pair that serves as a nice jumping-off point to starhop to the comet. Once you're at the comet's position, a roundish galaxy-like fuzzball should grace the field of view. If not, bump up the power to at least 100x, which helps the contrast. Test your skills to see if you can detect which side is more defined, where the solar wind blows back a weak tail.

Your best views of RX14 (LINEAR) will come after midnight at the start or end of the month when the Moon is out of the late-night sky.

An Asteroid Shadows Jupiter

Because asteroids were born in the same disk of dust and gas as the planets, it shouldn't be surprising that they travel in the same part of the sky as their big brethren. This month, asteroid 39 Laetitia parallels the brilliant beacon Jupiter. Because the main stars of Cancer are on the faint side, I usually use the head of Hydra as my base of operations.





From Epsilon (ε) Hydrae, slide 4° north (less than a binocular field) to 49 Cancri. Then use the chart to zero in on 10.1-magnitude Laetitia. This rock measures about 100 miles (160 km) across and has a moderately bright surface, some six times brighter than lunar soil.

Laetitia is well camouflaged among the background stars. The word *asteroid* literally means "star-like." If you're not sure which star in the field is the asteroid, make a quick sketch, then come back on another evening to see which one has changed position. It moves slowly enough that it takes two nights to travel the apparent width of our Moon across the sky. ▣

Martin Ratcliffe is President of the International Planetarium Society. Alister Ling is a meteorologist for Environment Canada.

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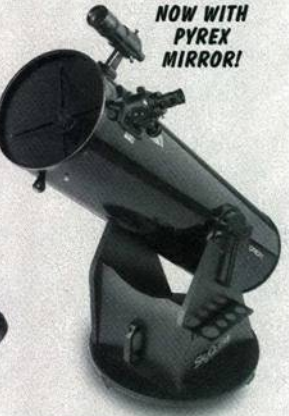

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SVP 100 & FREE drive **$499**

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Counting Stars, Earth's Tilt, Propulsion, Local Expansion

How do astronomers estimate the number of stars in the Milky Way Galaxy? I've seen numbers anywhere from 100 billion to 400 billion. That's quite a range! And do these estimates include the borderline almost-stars, the numerous brown dwarfs?
— Al Martin, Naperville, Illinois

One, two, three...

OK, that's not going to work. There are far too many to count.

The numbers you found for the stars in the galaxy span a range because no one really knows how many stars there are — it depends on many different variables. We cannot count or even make a good statistical sample because our vision can't penetrate very deeply into the interior of the Milky Way. There's too much absorption of starlight by interstellar dust.

So much for astronomy — but let's see where physics gets us.

The simplest approach starts with a determination of the galaxy's mass. The Sun has a more-or-less circular orbit around the center of the galaxy. To a reasonable approximation, it responds to the combined gravitational attraction of the stars that lie inside its orbit. Using Kepler's Laws as generalized by Isaac Newton, you can treat the galaxy and the Sun as a simple two-body problem, and derive the galaxy's mass. (This is just like finding the Sun's mass from Earth's orbit.)

Since the Sun orbits so far from the galactic center — about 28,000 light-years — most of the galaxy's stellar mass lies inside the Sun's orbit. But we need to make a small correction for the mass outside our orbit. When that's added in, the overall number comes out as a bit above 100 billion solar masses.

But that's mass, not stars. So it's back to astronomy.

Most stars are dim, cool M-type dwarfs. Figuring that the average star has about half a solar mass, we find between 200 and 300 billion stars. However, astronomers don't have a good handle yet on the number of the faintest M dwarfs, nor for brown dwarfs. These might double the number of stars derived above.

So in the end, between 200 and 400 billion stars seems reasonable. Clearly, however, we still have a lot to learn about our own stellar system. — *Jim Kaler, professor of astronomy, University of Illinois*

The Milky Way truly does contain "billions and billions" of stars. Mark Schroeder

How would life be different if there were no 23.5° tilt of Earth's rotation axis?
— Sam Platts, Sylmar, California

If Earth's axis stood vertical to the plane of its orbit, the Sun would rise and set in the same place every day as seen from any fixed location. Furthermore, the Sun would reach the same maximum height in the sky each day and shed the same warmth and light every day in the year. This unchanging cycle would eliminate the seasons.

If each part of Earth's surface received a more constant amount of heat from the Sun, this would also change weather patterns by creating a more steady east-west air flow than exists today. At present, seasonal heating and cooling of polar regions send large masses of air to different latitudes.

Another change is that Earth's axis would not precess, meaning that the location of the North Celestial Pole would remain fixed. Today there's a North Pole star called Polaris, which helped our ancestors navigate before compasses and other technology were available. Without the present tilt, the North Celestial Pole would lie in Draco, and there would be no bright North

Pole star to navigate by. This might have delayed the spread of humans over the oceans in the Northern Hemisphere of such an Earth.

In the Southern Hemisphere there is no South Pole star today, nor would there be one on an Earth without a tilt. Such a world would have a few dim stars, such as Delta, Epsilon, and Eta^1 and Eta^2 Doradus clustered around what would be the South Celestial Pole. Perhaps, on a tiltless Earth, these would enable deep-water navigation in the Southern Hemisphere to develop before it would in the north. — *Neil F. Comins, Department of Physics and Astronomy, University of Maine at Orono*

How do rockets propel themselves through space? — *Cam Crower, Pleasant Prairie, Wisconsin*

People often wonder how a rocket works, especially out in space "where there's no air to push against." The easiest way to understand a rocket engine is to blow up a balloon with air and tie the nozzle closed. Why doesn't it fly away? The answer is that the air pressure inside is balanced in all directions. The force pushing the balloon up is exactly balanced by a force pushing down, and the same holds for every other direction.

Now blow up another balloon, but this time simply hold the nozzle shut. Notice that just like the tied-off balloon, this one doesn't want to fly around; again, all the forces are in balance. But when you let go of the nozzle, the situation changes. Abruptly, the internal forces are no longer exactly balanced. More specifically, the force pushing ahead isn't counterbalanced because the air to do it is rushing out the nozzle. As a result, the balloon flies off.

A rocket engine's combustion chamber works the same way — it's a metal and ceramic balloon filled with extremely hot gases that push hard on the walls. With one end open, the forces are unbalanced in a forward direction — and we're go for liftoff. — *Robert Burnham, Contributing Editor*

This deep visible light and infrared view reveals distant protogalaxies in the infancy of the expanding universe. R. Williams (STScI), the HDF-South team, and NASA

If the expansion of the universe is due to space itself expanding and not galaxies flying apart through space, then shouldn't the space between the planets in our solar system also expand and thereby cause the planets to be moving farther apart? — *Jere Yost, San Bruno, California*

It would do exactly as you say except that on distance scales as small as within a solar system — or within a galaxy — the gravitational field of all the local matter overwhelms the gravitational force produced by matter lying at great distances. This means a gravitationally-bound collection of objects like a solar system behaves as a single unit from a cosmological point of view.

To back up a moment, it's not correct to say "space is expanding." What's expanding is space-time — that is, the gravitational field produced by all the matter in the universe is progressively weakening due to the expansion. (This is not the same thing as the notion that gravity is becoming weaker over time — those theories have not panned out. Instead, what's happening is that the universe is becoming less dense and as a result, the strength of its gravitational field at any given local point is decreasing.)

So where's the changeover point? Where do local effects give way to the universal? The scale on which things become "locally bound" is at about the size of clusters of galaxies. Within these structures, the formation of galaxies, as well as stars (and planets) within galaxies, is governed by the strength of the local gravitational field relative to the universe's rate of expansion. Another way to say this is that wherever the local material has enough mass that its gravitational field dominates the universal field, matter will form into small-scale structures such as galaxies and stars.

In fact, this is how structure forms in any cosmological model. When astronomers look at the first structures to emerge in the early universe, this principle helps them estimate how much matter, dark and light, the early universe contained. — *Steven Shore, professor of astrophysics, Indiana University at South Bend* ■

CONTACT INFO

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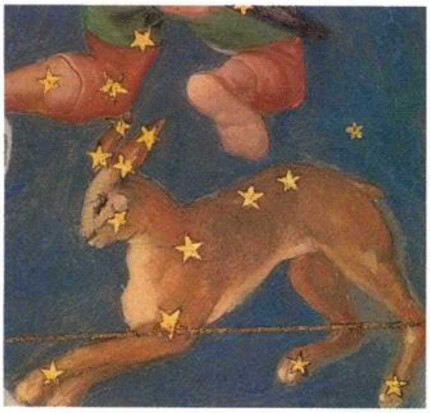
Lepus and Columba



Admire the stars, nebulae, and galaxies in the habitats of the Hare and the Dove.

by Tom Polakis

Winter evenings usher in the bright, nearby stars of the constellations Orion, Gemini, and Auriga. The band of the Milky Way opposite our galaxy's center shines brightly. Tucked away directly south of Orion are two small constellations that are far enough off the galactic plane to show galaxies, but still contain clusters and nebulae in our home galaxy.

Lepus the Hare holds eight stars brighter than 4th magnitude, and the form of a rabbit can indeed be made out with some imagination. Over 1,000 light-years away, Alpha (α) Leporis is both the brightest and most distant of the constellation's naked-eye stars. Diagonally opposite in the constellation's central four-star pattern, Gamma (γ) Leporis is an ordinary, sunlike star only 29 light-years away. Lying in the southwest corner of the constellation, Epsilon (ε) Leporis is a spectral type K4 giant that appears orange to the naked eye.

Columba the Dove lies to the south of Lepus and rides low along the horizon for northern viewers. Similar to Lepus, the constellation becomes more starry from west to east. α Leporis is a Be star that shows emission lines likely associated with a circumstellar disk.

Near the border of Lepus and Eridanus is the spectacular carbon star **R Leporis**. Also called Hind's Crimson Star, it is one of the sky's reddest and varies regularly between 6th and 12th magnitude. It currently falls near the faint end of this range, so use low magnification and gaze directly at the star to detect its ruddy hue.

Just over 1° to the southeast, a huge planetary nebula proves to be a challenge for backyard telescopes. The shell of **Abell 7** measures 150 light-years across. Seen from a distance of 40,000 light-years, this translates to an angular size of over 12'. This planetary is in late evolutionary stages, appearing on photographs as a giant bubble with a thin rim. At a dark-sky site, a 13-inch telescope with a nebula filter at low power faintly reveals a diffuse, glowing disk with a sharp edge. Removing the filter and raising the magnification shows the central star, but the planetary nebula vanishes from sight.

West-northwest of α Leporis the barred spiral galaxy **NGC 1832** lies in the same telescopic field as Mu (μ) Leporis. In a 10-inch scope, the galaxy is 3' by 2', with its major axis oriented north-south. It possesses a small, broadly concentrated core and a very faint halo. NGC 1832 has a flocculent spiral structure characterized by discontinuous, patchy arms. In larger telescopes, the thin, eastern arm is better defined and seems detached from the galaxy.

Near the border of Orion, **IC 418** is a young planetary nebula that exhibits a unique color. At first glance, it seems like an ordinary disk planetary with a very bright central star. A long, direct gaze at medium magnification in a large telescope brings out a pink hue. A 10-inch telescope shows this color with difficulty, but a 16-inch cinches it. Magnifications greater than 200x seem to spread the light out too much for the color to be apparent. The disk has a diffuse edge, and its visibility is not enhanced with a nebula filter. The bright central star of IC 418 varies irregularly by a couple tenths of a magnitude over a period of several hours. Pulsation seems to best explain the variability. While only the inner shell is visible optically, radio observations reveal a larger ionized halo

Artwork from *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.

NGC 1851

NOAO

and a still larger halo of neutral gas measuring over 1' in diameter.

Slew 4° south-southwest of ε Leporis to find **NGC 1744**, a bright, barred spiral galaxy. This is an isolated galaxy in a relatively pristine state, showing no indication of interactions with other galaxies in its lifetime. Although we view it from only 30 million light-years away, observable detail is surprisingly fleeting. NGC 1744 is faint and measures just 3' by 2' in a modest scope, which misses the outer halo. Its core is broadly concentrated, and the periphery has an irregular outline. A 13th-magnitude star lies just to the west. The field is quite starry, adding some foreground to the scene.

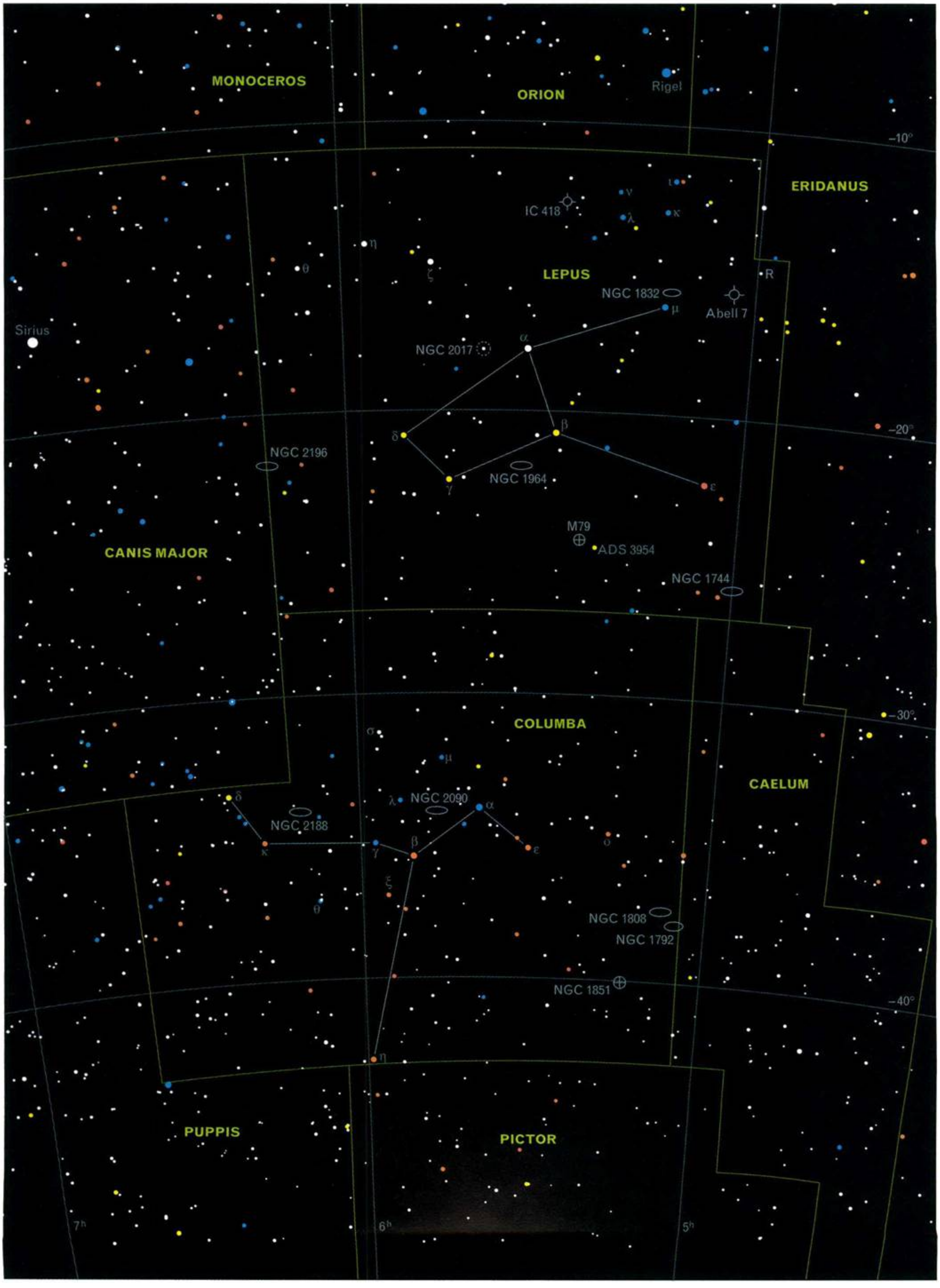
M79 (NGC 1904) is the most southerly Messier object in the winter sky. Extend a line southward from α through Beta (β) Leporis to find it. This globular cluster is among the oldest known in the Milky Way. Situated far from the galactic center, M79 is a nearby halo cluster 40,000 light-years away. For all of its brightness, it is a difficult globular to resolve in smaller instruments. A 10-inch scope shows a bright, broadly concentrated core nearly devoid of stars and scores of resolved stars at the edge that are as bright as 13th magnitude.

Just over 0.5° west-southwest of M79 is a pretty double star. **ADS 3954** has a tight separation but is easily resolved in a 60mm telescope on a steady night. Look to the east of the yellowish primary at a magnification of 100x or higher for a white companion that is about one magnitude fainter.

Slew just over 3° northeast of M79 to land on **NGC 1964**, a small spiral galaxy about 80 million light-years away. In a

NGC 1964

Martin C. Germano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Deep-Sky Objects in Lepus and Columba

Object	R. A. (2000.0)	Dec.	Mag.	Size/Sep./Per.	Type	Notes
R Leporis	4h59.6m	–14°48'	5.5–11.7	432 days	Var	Hind's Crimson Star
NGC 1744	5h00.0m	–26°01'	11.3	5.1' by 2.5'	Gal	SB(s)d
Abell 7	5h03.2m	–15°36'	13.2	770"	PN	
NGC 1792	5h05.2m	–37°59'	9.9	5.5' by 2.5'	Gal	SA(rs)bc
NGC 1808	5h07.7m	–37°31'	9.9	5.2' by 2.3'	Gal	(R)SAB(s)a
NGC 1832	5h12.1m	–15°41'	11.3	2.1' by 1.5'	Gal	SB(r)bc
NGC 1851	5h14.1m	–40°03'	7.2	11'	GC	
ADS 3954	5h21.8m	–24°46'	5.4/6.6	3.5"	Dbl	
M79 (NGC 1904)	5h24.2m	–24°31'	7.8	8.7'	GC	
IC 418	5h27.5m	–12°42'	9.3	12"	PN	Spirograph Nebula
NGC 1964	5h33.4m	–21°57'	10.7	5.0' by 2.1'	Gal	SAB(s)b
NGC 2017	5h39.3m	–17°51'	—	10'	OC	
NGC 2090	5h47.0m	–34°15'	11.0	4.5' by 2.3'	Gal	SA(rs)c
NGC 2188	6h10.2m	–34°06'	11.6	5.5' by 0.8'	Gal	SB(s)m
NGC 2196	6h12.2m	–21°48'	11.1	3.0' by 2.5'	Gal	(R')SA(s)a

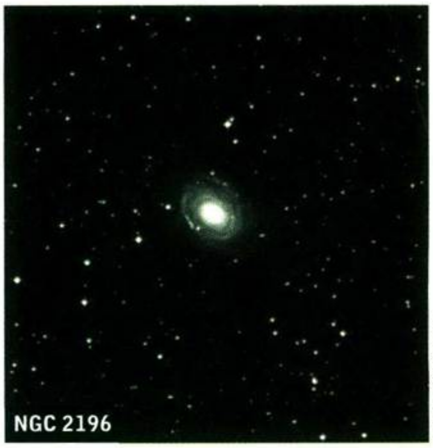
Object: Designation in Messier, NGC, or other catalog. **R. A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size/Sep./Per.:** Size in arcminutes or arcseconds; separation in arcseconds; period in days. **Notes:** Hubble types for galaxies.

NGC 1792

Digitized Sky Survey

M79

Dale K. Bonges


NGC 2196

Digitized Sky Survey

12-inch telescope, it is very faint, revealing only the inner 2' by 1' haze surrounding a very bright core. Several bright stars lie just west of the galaxy, and four superposed 13th-magnitude foreground stars masquerade as supernovae.

Working our way northward through Lepus, we come upon an attractive multiple star system misidentified in catalogs as an open cluster. **NGC 2017** contains three 8th-magnitude stars closely crowded around a 6th-magnitude star. Several fainter stars contribute to the illusion that this is an open cluster. Be sure to magnify the bright central star of the system, as it resolves into a subarcsecond double.

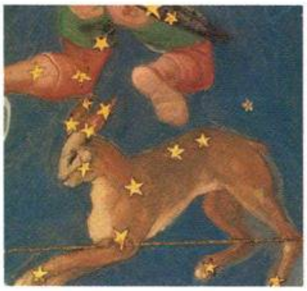
The bright spiral galaxy **NGC 2196** straddles the Canis Major border. Even in a large telescope the galaxy is no more than a small, round haze less than 2' in diameter with a large, much brighter center. Deep photographs bring out delicate spiral arms around a broad disk. Look for a tiny, elongated triangle of stars near the galaxy's south end.

We now move into Columba, where a prominent galaxy pair resides. **NGC 1792** is a disturbed spiral that interacted with nearby NGC 1808 in the recent past. Luminous HII regions peppering the galaxy are sites of active star formation. Only 35 million light-years away, NGC 1792 is a bright object for backyard scopes. A 13-inch telescope shows signs of the galaxy's interaction in its irregular shape, which departs from a typical oval. It is 3' by 1' and nearly uniform with little central brightening. High magnifications show some sign of mottling at the southeast end and a faint embedded star to the northwest.

To the northeast in the same low-power telescopic field lies the partner galaxy **NGC 1808**. In smaller telescopes the elongated halo extends to nearly 4' in length and surrounds a nearly stellar core. A large scope at a high and dry site brings out some mottling across the face of the galaxy, although the dim spiral arms remain elusive. NGC 1808 possesses a

The Hare and the Dove

I heard the sky-lark warbling in the sky;
And I bethought me of the playful hare:
Even such a happy Child of earth am I;
Even as these blissful creatures do I fare;
Far from the world I walk, and from all care.
Resolution and Independence, *William Wordsworth (1770 – 1850)*



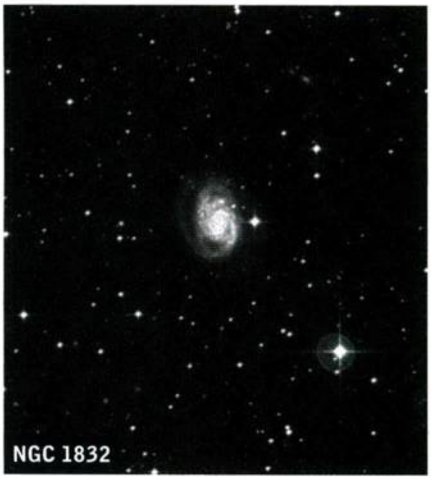
Crouching at the feet of Orion, Lepus is one of many creatures in the sky in conflict with another. Although the Hunter is largely preoccupied by the charging Taurus, his dogs are focused on their eternal pursuit of the Hare.

It isn't clear who first regarded the relatively faint stars to Orion's south as an animal. The Greeks referred to the constellation as Lagos, which means rabbit or hare, and the brightest star in Lepus is named after the Arabic word for hare, Arneb.

One ninth-century astronomer, however, referred to the constellation's four primary stars as the Four Camels, which are making their way toward Eridanus for a drink from the River.

Egyptians looked upon Orion as their sun god, Osiris, and at the stars beneath his feet as carrying him across the heavens. So Lepus has also been known as the Boat of Osiris.

Easily unnoticed with its faint stars and unshapely layout, Columba flies peacefully across the southern skies. To many it represents the dove Noah sent from his ark to search for dry land following the global flood. The dove returned with an olive branch in its beak and now remains as a permanent symbol of peace for those who seek it.



NGC 1832

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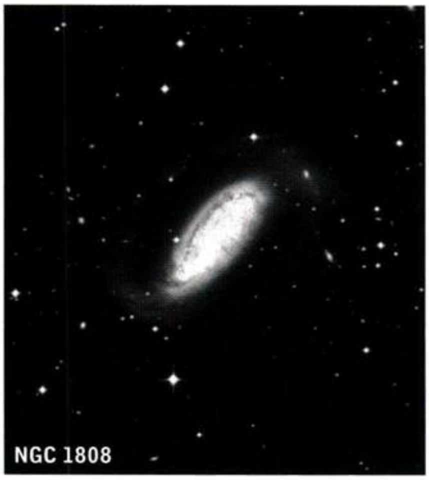
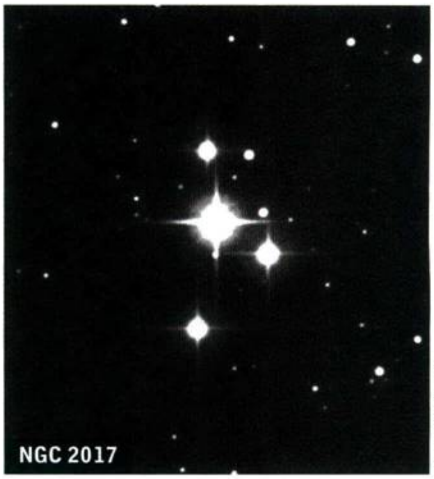


NGC 1808

Digitized Sky Survey



NGC 2017

Preston Scott Justis

ring of active star formation and "hot spots" near the core. It is similar in structure to the barred spiral galaxy NGC 7479. The pair formed by NGC 1808 and NGC 7479 is joined by three fainter galaxies to form a small group.

Not far to the south-southeast of the previous galaxy pair is another halo globular cluster. **NGC 1851** resides 40,000 light-years from the Sun and 50,000 light-years from the galactic center. The view is pleasing in any telescope. A very concentrated core is surrounded by scores of stars that resolve well, especially at the sharply defined edge. The full extent of NGC 1851 when viewed through a large telescope is nearly 6' in diameter.

From α Columbae, it's a 1.5° pan to the east to the bright spiral galaxy **NGC 2090**. A diffuse halo about 2' long and half as wide is elongated east-west around a broadly concentrated core. A 10-inch scope shows a thin, diffuse region around the periphery. Long-exposure images reveal a multitude of much fainter, choppy spiral arms that require very large aperture to detect. The distance to NGC 2090 is about 40 million light-years.

NGC 2188 rounds out this month's collection of objects. This is a large irregular dwarf galaxy with a disk that is inclined only 3° from edge-on. Its brightness is attributed to proximity — only 25 million light-years away. It appears moderately bright in a telescope and is nearly five times as long as it is wide. The surface brightness is low and evenly distributed. A large scope shows the large HII region as a subtle brightening at the south end of the galaxy.

Tom Polakis is an aerospace engineer by day and an observer and astrophotographer by night. He lives in Tempe, Arizona.

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The Sky's TOP 10

by Kelly Kizer Whitt

Kelly Kizer Whitt is a freelance writer who observes from her home in Wisconsin. A former copy editor of Astronomy, she wrote the terrestrial planets section for The Illustrated Encyclopedia of the Universe.

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Starry-eyed. Moonstruck. The words we use to describe that giddy, pulse-quickening rush of infatuation are often heaven-sent. The fact that the vernacular of love is so entwined with the sky is a testament to our deep, abiding devotion to it. But what happens when the thrill starts to fade?

Dedicated deep-sky observers have seen the Andromeda Galaxy and other popular hot spots time and again. And as in love, familiarity can breed indifference. But it doesn't have to. Every star has a story. As you gaze at each deep-sky beauty, you may see it in a new light if you recall its history or what its future holds. Rekindle your romance with the following 10 deep-sky objects, judged to be the best by *Astronomy.com* forum members.

Share your experiences observing and photographing these targets in the Top 10 Deep-Sky Objects forum on *Astronomy.com*. If you're an astrophotographer, send digital copies of your photos to gallery@astronomy.com. Please include "Top 10 Deep-Sky Objects" in the subject heading. If selected, your image will appear in *Astronomy.com*'s Photo Gallery.

10 NGC 869 and 884

Nickname: Double Cluster
Constellation: Perseus
Magnitudes: 4
Distance: 7,400 light-years

Double your pleasure, double your fun — in Perseus you'll find two clusters instead of one. Located in the Greek hero's sword handle, the two clusters are sometimes designated h and chi Persei. Visible with the naked eye as a fuzzy patch between the brightest star in Perseus and the brightest star in Cassiopeia, each cluster measures about 0.5° across. NGC 869 (h) contains about 200 stars and NGC 884 (chi) has about 150.

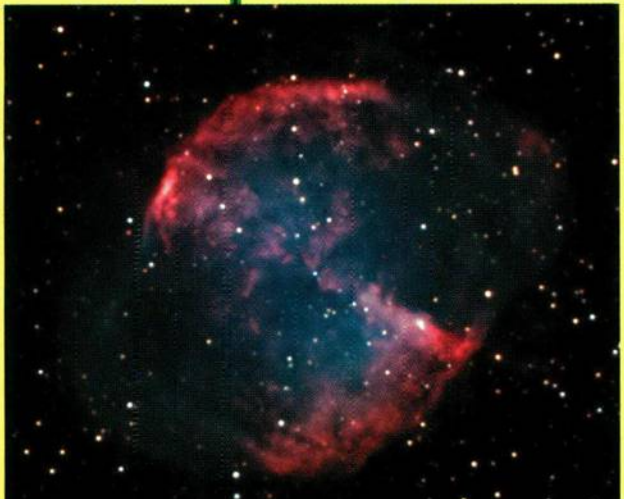
The stars are young and some may still be forming. The brightest are classified as O or B stars. The two clusters mark the center of an area called the Zeta Persei association, defined by stars that grew from a concentration of gas and dust in one of the Milky Way's six spiral arms.

The Double Cluster lies within the Perseus Arm, while we lie in the Orion Arm. The other four arms are Cygnus, Centaurus, Carina, and Sagittarius. The Perseus Arm curls around our position opposite the Milky Way's center.

Akihiko Nimura

9 M27

Nickname: Dumbbell Nebula
Constellation: Vulpecula
Magnitude: 7.6
Distance: 1,250 light-years



Tim Hunter and James McGaha

You may be the offspring of a dumbbell. That's not trash talk about your parents, but a description of how the universe produces the heavy metals that make up our bodies and our environment. The dumbbell, or hourglass, shape is common among planetary nebulae, which form when a sunlike star reaches the end of its life and expels its material into space. Astronomers have identified about 1,500 planetary nebulae in our galaxy, and of those, the Dumbbell Nebula is the easiest for small telescope owners to observe.

Planetary nebulae last no more than 50,000 to 100,000 years before they disperse so much they are too faint to be seen. At that point, they mingle with other interstellar material, to be incorporated into the next star and planetary system. In this way, planetary nebulae are somewhat accurately named, because they provide fuel for future planets. Originally, astronomers called them planetaries because they resembled giant gas planets through the crude telescopes available at the time.

8

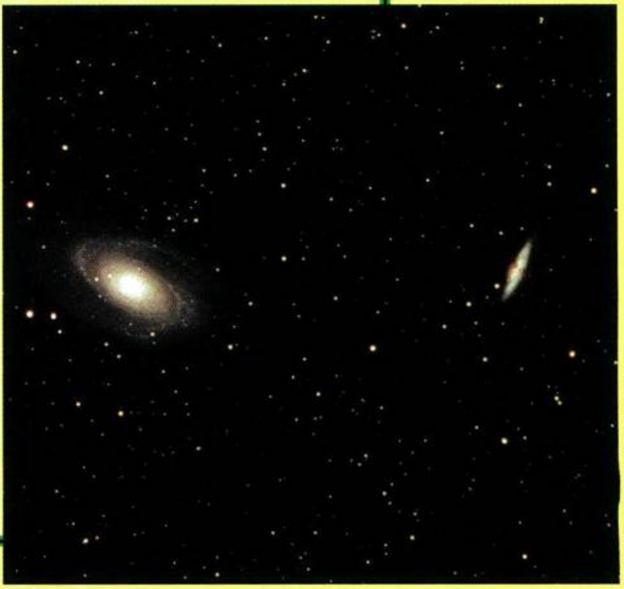
M81 and M82

Nickname: Bode's Nebula and the Cigar Galaxy
Constellation: Ursa Major
Magnitudes: 6.9 and 8.4
Distance: 12 million light-years

M81's nickname, Bode's Nebula, is a misnomer because it is actually a spiral galaxy. Its namesake, German astronomer Johann Elert Bode, first spied the "nebula" in 1774, before any deep-sky objects were known to be extra-galactic in nature. M81's next-door neighbor, M82, is a spiral galaxy nicknamed the Cigar Galaxy due to its unusual shape.

The spiral galaxies orbit each other with particularly close passes every 100 million years, causing outbursts of star formation in each. M82 also has strong x-ray emission and appears brighter in infrared light than any other galaxy. The young star clusters are also brighter than any in the Milky Way. With a separation of only 150,000 light-years between their centers, the two will become one in a few billion years.

Although M82's colorful filaments yield more interesting photographs, M81 has the more intriguing story. What you see here is what you get, because unlike the Milky Way and other galaxies we are familiar with, M81 seems to have very little dark matter. The galaxy's rotation curve drops off as you head outward, indicating that most of its mass is where it appears to be: at the center.

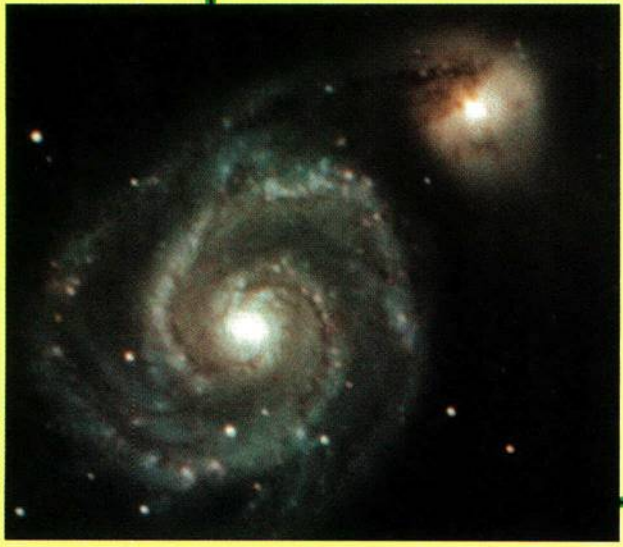


Carl W. Weber, III, and Chris Weber

7

M51

Nickname: Whirlpool Galaxy
Constellation: Canes Venatici
Magnitude: 8.4
Distance: ~37 million light-years



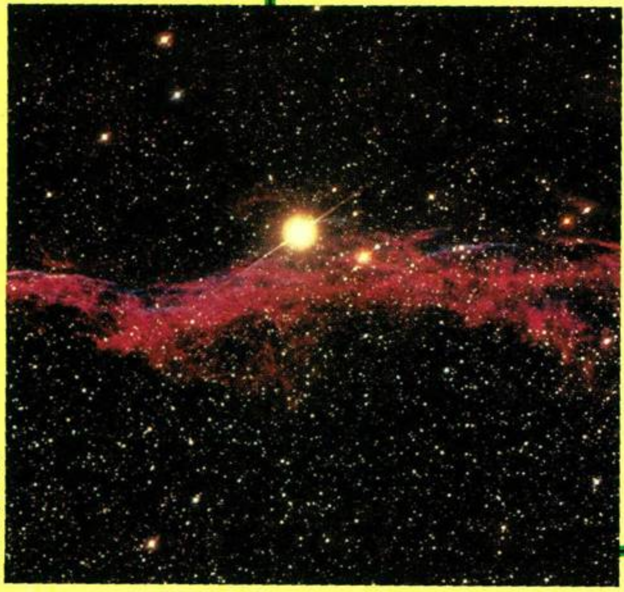
Jean-Luc Dauverene

Our own Milky Way Galaxy is a spiral, and so is the nearest large galaxy visible to the naked eye, Andromeda. But it was M51 in which astronomers first detected spiral structure. Named for its shape, the Whirlpool Galaxy lies in a revealing face-on position as seen from Earth. Charles Messier discovered it in 1773, and William Herschel noted it as ring-like through his 18-inch reflector. It was not until William Parsons, the third Earl of Rosse, turned his 6-foot reflector on it in 1845 that its spiral nature was first noticed.

At that point, all galaxies were still classified as nebulae, because their true nature was not known. Pierre Simon Laplace thought nebulae were solar systems in the process of forming. Laplace postulated that the planets formed from rings that separated and condensed from a large, rotating cloud of gas. The discovery of spiral structure seemed to support his nebular hypothesis. But eventually the Whirlpool was identified as a galaxy, and instead of a handful of planets spiraling about it, billions of stars compose the disk.

6 NGC 6992, NGC 6995, NGC 6960, and NGC 6979

Nickname: Veil Nebula
Constellation: Cygnus
Magnitude: 5
Distance: 1,400 light-years



Bill and Sally Fletcher

The Veil Nebula has several designations because of its large size — it spans more than six times the Moon's diameter in the sky. This huge nebulosity is part of the Cygnus loop; it's a supernova remnant from a star that exploded between 5,000 and 15,000 years ago. The gaseous debris slammed into a nearby gas cloud and caused the filaments to glow.

Supernova explosions provide one of the greatest risks to life on Earth. These tremendous explosions are strong enough that we can see them even when they occur in galaxies far away. A supernova in our galaxy and within 30 light-years of Earth would extinguish life on our planet. Fortunately, there are no stars within that distance likely to explode in a supernova, at least not within the next few million years.

Supernova candidates that we can see with the naked eye include Betelgeuse in the constellation Orion, and the Southern Hemisphere splendor Eta Carinae in the constellation Carina. Eta Carinae is a safe 8,000 light-years away. Betelgeuse is approximately 520 light-years distant, about three times closer than the star that produced the Veil Nebula. When Betelgeuse explodes, the high-energy particles that reach Earth (if we are still around) will cause regular auroral displays.

5 M57

Nickname: Ring Nebula
Constellation: Lyra
Magnitude: 8.8
Distance: 2,000 light-years

When looking at most deep-sky objects, we are getting a glimpse of the past. But M57 allows us a vision of our future. This ring-shaped planetary nebula was once a star not much larger than our Sun. As it burned up all its available fuel and came to the end of its life, it puffed off its outer layers, revealing a core that had condensed to the size of a terrestrial planet. The Sun will one day follow in its footsteps and become a white dwarf with a nebular shroud. The center star is visible through large telescopes as a 15th-magnitude bluish-green speck. If our Sun were placed at the center of the Ring Nebula, the nebula would extend about 500 times farther than our entire solar system.

The expanding ring rushes outward from the white dwarf at a rate of about 12 miles (19 km) per second. The nebula was once thought to be spheroidal, but new research suggests its nickname, the Ring Nebula, is relatively accurate. We are viewing M57 from the vantage point of one of its poles, and the stellar remains are barrel- or tube-shaped.

Jack Marling

4 M13

Nickname: Hercules Cluster
Constellation: Hercules
Magnitude: 5.8
Distance: 23,500 light-years

Discovered by Edmond Halley in 1714, M13 is a globular cluster visible to the naked eye on dark summer nights. If Earth were orbiting a star in a globular cluster like M13, the night sky would be filled with bright lights from nearby suns, and it would be very difficult to study other portions of the galaxy or universe.

In 1974 one of the first radio messages sent from the Arecibo telescope in Puerto Rico was beamed at M13 with the hopes of making contact with an intelligent civilization. The message will take 23,500 years to cross the gulf between us and "them."

And chances are the message will find no one to receive it. A search for planets in another of the Milky Way's globular clusters, 47 Tucanae, came up surprisingly empty. Astronomers are not sure why — planets are found around stars throughout the Milky Way. One possible explanation is that globular cluster stars formed early and therefore contain fewer heavy metals (each successive generation of stars produces heavier elements) that make up terrestrial planets. And any planets that do form might be flung out of their orbits or destroyed through tidal interactions in such close quarters.

K. Zussman

3 M8 and M20

Nickname: Lagoon and Trifid Nebulae
Constellation: Sagittarius
Magnitudes: 5.8 and ~9
Distance: 5,200 light-years

Mike Fiest

Located in the direction of the Milky Way's center in Sagittarius, this star-rich area contains two popular nebulae. M8, also known as the Lagoon Nebula, is the larger and brighter of the two and shows up more easily in binoculars. M20 is dimmer with more of its light obscured by dust lanes known as dark nebulae. The branching dark nebula trisecting M20 (appropriately named the Trifid Nebula) carries the label B85. M20's length of 0.5°, compared to M8's 1.5°, helps make it more difficult to spot. But the two are commonly paired together due to their proximity in the sky.

Both objects have distance estimates of 5,200 light-years, but in reality they may be quite a bit farther apart. Difficulties in making distance measurements could mean M20 lies as close as 2,000 light-years or as far away as 9,000 light-years.

Both nebulae are categorized as the emission type (although M20 also has some reflection qualities). This puts them in the same class as the Orion Nebula. Emission nebulae shine because their gas and dust are being heated by a nearby source (usually young neighboring stars). M8's power station is a 6th-magnitude blue supergiant, 9 Sagittarii, while M20's is a multiple star system, HN40.

2 M31

Nickname: Andromeda Galaxy
Constellation: Andromeda
Magnitude: 3.4
Distance: 2.3 million light-years

George Greaney

M31, the giant Andromeda Galaxy, requires no optical aid to see in locations with little light pollution. This means you can look up in the sky with your naked eyes and see back in time more than two million years, due to the galaxy's great distance and the time it takes for its light to reach our eyes. Small telescopes may pick up Andromeda's two 8th-magnitude companions, the elliptical galaxies M32 and M110 (NGC 205). M31 exhibits an odd double nucleus, due to either the consumption of a small galaxy or possibly just a visual artifact from an intervening dust lane.

As the nearest spiral galaxy and largest member of our Local Group of galaxies, M31 exhibits a blueshift, which means that it is moving toward us, rather than away from us like the millions of other galaxies becoming ever more distant due to the expansion of the universe. Our local group is bound by a force stronger than this repulsion — gravity. Eventually M31 and the Milky Way will merge, and this new super-sized galaxy will probably grow even larger. The massive Virgo Galaxy Cluster, which now exhibits a redshift, contains such a strong well of gravity that astronomers believe our motion apart will come to a stop and then appear as a blueshift as we begin to barrel toward it.

And the Winner is...

1 M42

Nickname: Orion Nebula
Constellation: Orion
Magnitude: 4.0
Distance: 1,500 light-years

Found around the middle sword star in Orion, M42 is visible to the naked eye as a misty patch 1° in diameter. Four stars known as the Trapezium, ranging in brightness from magnitude 5.1 to 8.0, ionize the nebula, which then glows. At 20 to 30 light-years in diameter, the entire nebula makes up the near end of the Orion Molecular Cloud. A separate section of the nebula bears the label M43, or de Mairan's Nebula. A small dust lane sections off the northeast portion, a distinction first reported by Jean-Jacques Dortous de Mairan in 1733.

In 1880, Henry Draper put M42 on film, making the first successful photograph of a nebula. Since then, the Hubble Space Telescope has frequently chosen it as a target. These images have revealed "proplyds," or protoplanetary disks — young stars surrounded by orbiting gas and dust that may someday become planets. But the blistering radiation makes planet formation difficult, blasting away much of the building material. Near-infrared images of the Orion Nebula have shown dozens of newborn brown dwarfs (the "missing link" between stars and planets) among the stars of the Trapezium cluster. These failed stars are at a young enough stage that they are still hot and bright, allowing them to be detected.

Robert Gendler

Test-driving Meade's LX90

Meade's trusted optics and proven computer technology unite for a happy medium in reliability and price.

Text by John Shibley

Photos by William Zuback

THE LX90 IS AN 8-INCH SCHMIDT-CASSEGRAIN telescope on a computer-controlled mounting. Such instruments, called Go-to telescopes, now exist in virtually all size ranges and have become deservedly popular. They make it easy for beginners to explore the sky and grant experienced observers more time looking at objects than hunting them.

Within the universe of Go-to scopes, the LX90 is a mid-priced, mid-sized instrument. After testing it for several weeks, I deem its performance impressive.

The LX90, like most Go-to scopes, has an alt-azimuth mounting. This means no polar alignment, often a bugaboo for beginners. Instead, the user does a short setup routine to level the field tripod and swing the scope north. Then one follows prompts from LX90's built-in computer to orient the telescope to the sky. Elapsed time: about two minutes. Thereafter the motors in the mounting run in tandem to slew to targets and keep them centered.

Silicon Cosmos

The heart and soul of any Go-to telescope is its computer control, and the LX90's is called Autostar. It's essentially a hand-held computer that runs all aspects of the telescope's powered operation.

When Go-to scopes arrived on the market about 10 to 15 years ago, they were prone to crashes and frequent bouts of pointing confusion. More often than not, you had to reboot the system many times during the course of an evening.

That was then; this is now.

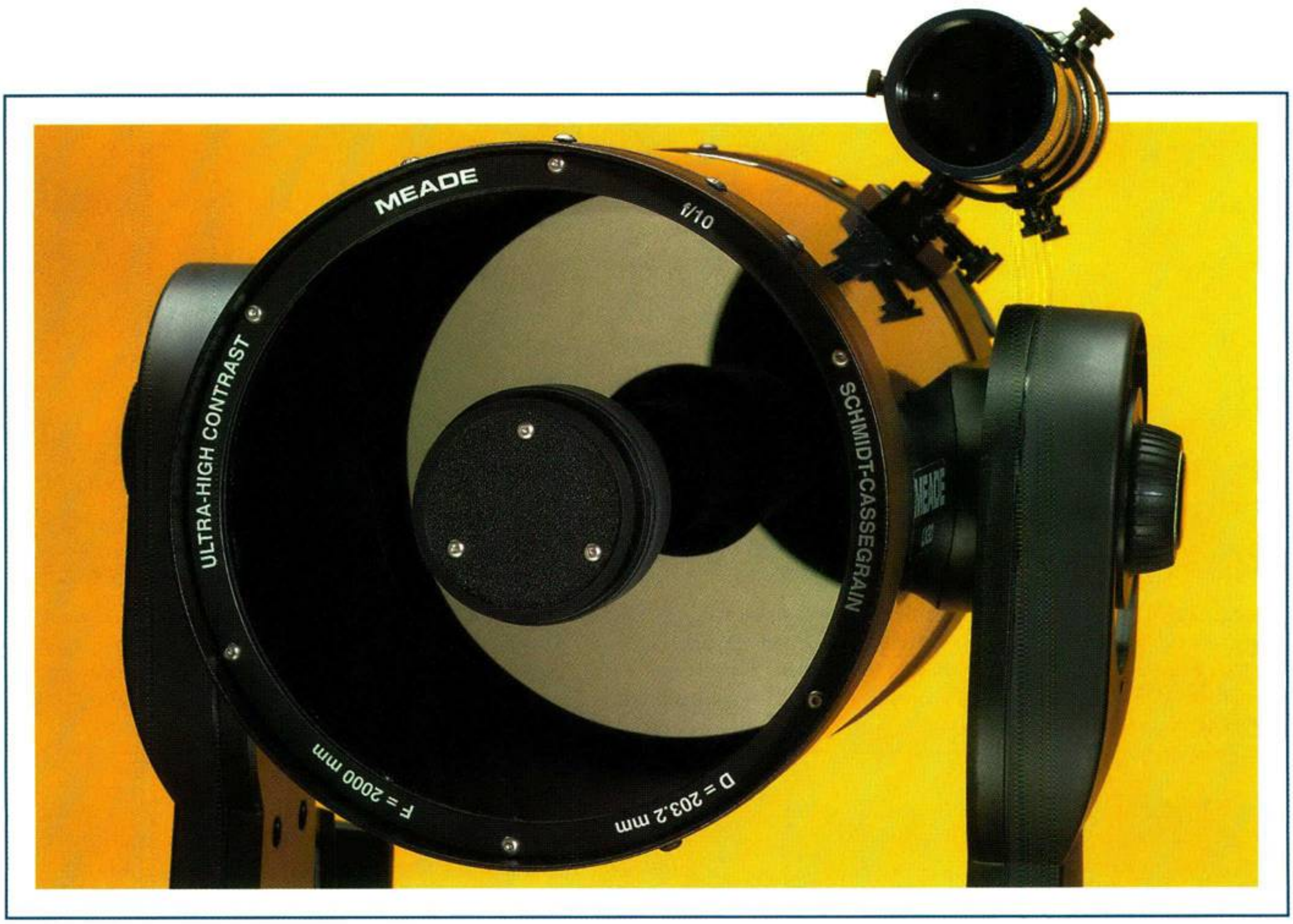
The Autostar represents a mature technology. I tried everything to make the controller's computer seize up: pushing buttons out of sequence, bailing out of a Go-to selection in mid-slew; however, nothing caused the system to crash.

Beyond its reliability, the Autostar provides an exceptional guide to the night sky. It offers tens of thousands of targets programmed into a database that covers deep-sky objects, stars, planets, and asteroids. In addition, it provides three guided tours. "Tonight's Best" took me through some of the brighter deep-sky objects. (There were no evening planets at the time.) The others present a selection of distant targets and survey objects along the milestones of a star's life.

I looked up and slewed to 50-plus targets in the space of just one hour. These included all the Messier objects above the horizon, several favorite NGC deep-sky objects, double stars, and one asteroid, 2 Pallas, nestled in the stars of Pegasus. I chose targets by scrolling through Autostar's itemized menu and then hitting "Go-to." Each slew landed to within 10 arc-minutes of a target, well within the field of view of a medium-power eyepiece. Drive motors kept it centered; after 15 minutes I noticed a slight drift.

The Autostar can find and track a preloaded selection of 50 artificial satellites. I located the near-geosynchronous Satcom 3 – it was uncanny to watch this faint "star" hold practically stationary in front of a backdrop of moving stars.

The orbits of most artificial satellites in low-Earth orbit, including those listed in Autostar's database, change often as objects get reboosted or suffer from atmospheric drag. You can download updated elements directly into Autostar from the



Contrast-boosting optical coatings show up as a blue sheen on the front corrector plate.

Internet through a cable kit sold by Meade. This same cable uploads automated sky tours that can be written on a PC with any word-processing software.

Through an event menu, Autostar tells you when upcoming lunar phases will occur. It also gives local rise and set times for the Sun and Moon. When's the next minimum brightness of Algol, a variable star in Perseus? Punch it up in Autostar's memory for the answer.

Autostar's display has two 22-character rows of red LEDs. I found it difficult to read face-on, especially when information was scrolling quickly across the display face. Tilting the display 30° or so from face-on helped improve readability. The display's brightness and contrast is adjusted through Autostar's "Utilities" menu. A red LED built into the handset helps in reading charts or locating a piece of equipment.

Autostar's keypad directly accesses slew rates from 0.5° per second to 6.5° per second. If for some reason a target isn't centered after hitting Go-to, Autostar offers a feature called spiral search. The telescope's drive motors fire simultaneously to drive the scope in a slow spiral pattern outward from the original field you land on. This search pattern is programmed to overlap half the field of view yielded from a medium- to low-power eyepiece by about 18'. If you want to drive the telescope manually, use Autostar's drive-rate options and directional arrow keys to slew the scope. You can even aim it by the old-fashioned method of eyeballing targets through the 8x50 finder scope.

The scope's drive motors are inaudible at the slower slew rates. I noticed them only at the top four slew speeds. This contrasts with earlier motor-driven, variable-speed telescopes, which often sounded more like a grinding food processor rather than a telescope under the stars.

The LX90 gets power through eight C-cell batteries that slip into the telescope's fork base. These power both the drive motors and Autostar. The LX90 is an energy miser, saving enough power that the same set of batteries lasted four trips into the field, all filled with several hours of relatively aggressive slewing. These were "warm-weather" observing sessions in late summer, where lows dipped into the mid-40s Fahrenheit. Temperatures at or below freezing typically cut battery efficiencies in half or worse. Hence, it would be wise in the long run to supplement or even replace the batteries with an optional power cable that powers the scope from an external battery or AC power.

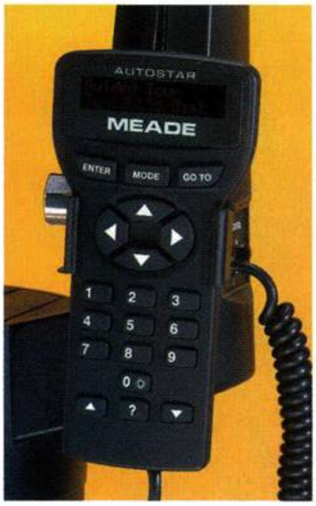
I also advise purchasing two LX90 accessories right away. Don't count on re-stowing the telescope in the original shipping box; mine broke apart during unpacking. Meade offers a soft storage case, or you can buy a foam-lined footlocker at many mass retailers. Another accessory to consider is a dew cap. This cylindrical attachment slips over the scope's front and reduces the amount of moisture that forms on the corrector plate. On damp evenings, the exposed corrector plate of Schmidt-Cassegrain telescopes typically starts dewing up in less than 10 minutes.

Appraising the Hardware

The LX90 contains a surprisingly small amount of plastic. Most components in the optical tube assembly and field tripod

Meade's LX90 8-inch SCT combines old favorites like reliable optics and sturdy mounting with proven computer technology.

Meade includes an 8x50 finder scope, 26mm Super Plössl eyepiece, and 1.25-inch star diagonal with this scope package. For long exposure images, astrophotographers will need an 8-inch equatorial wedge.



Powered up, the Autostar uses a two-line by 22-character LED screen, plus a keyboard for choosing objects and controlling the telescope's motions.

COMPUTER CONTROL
AUX
HBX
ON
OFF
12v
AUX

Auxiliary ports accept power cords and other accessories, such as autoguiders and CCD cameras.

are made of cast or machined aluminum. Aluminum passes heat readily and cools to surrounding temperatures faster than most other materials.

Telescopes with sealed optical tubes, such as Schmidt-Cassegrains, Maksutovs, and refractors, often provide unsteady views until they cool to the ambient air temperature. Tube currents inside the LX90 died down 45 minutes after heading out into temperatures of between 45° and 55° F. This occurred after the telescope sat in a hot garage all day.

The only plastic components that concerned me were the tightening knobs on the tripod legs. Even though they felt durable and seemed to hold up well, I hesitated to tighten them firmly for fear of twisting the knobs off the set studs that thread into the tripod. Switching to metal knobs might improve the feel of durability without greatly increasing Meade's manufacturing costs.

Overall, though, I was impressed with Meade's chromed-steel tripod. The legs are two inches wide. An interior metal spreader cinches tight against the legs as you thread a mounting bolt through the tripod head into the telescope's base. This adds sturdiness. Be sure to use care when mounting the telescope on the tripod. I found that the long mounting bolt had a tendency to cross-thread. Also, lifting and positioning the 30-pound scope-and-fork into place is almost a two-person job. If a second pair of hands is offered, accept the help.

It's best to have the scope's mount as level as possible. When the telescope's virtual horizon doesn't match the actual horizon, pointing errors accumulate over an evening. Meade doesn't include a bubble or spirit level with the LX90's field tripod, so I bought one at a camera supply store for less than $5. It fit rather nicely on the tripod head.

If you're set up in an area with unobstructed horizons, use Autostar's easy alignment routine. This option allows Autostar to select the evening's best-placed alignment stars from its memory, depending on time and location.

If your site has trees or something else blocking part of the sky, there's a quasi-manual alignment option. Choose two stars you can see that are widely spaced in the sky, using Autostar's menu of bright stars (listed alphabetically by classical name). Beginners should identify the bright stars by referring to the manual's basic star map or looking at the sky map printed each month in *Astronomy*.

A handy "park" option in the Utilities menu remembers the scope's alignment as long as you don't relocate the instrument.

Optics under the Sky

I discovered on my first night out that shipping had bumped the secondary mirror slightly out of optical alignment. Even though the misalignment bordered on negligible, I took a few minutes to adjust the optics for best performance.

The procedure is easy and thoroughly covered in the instruction manual. When the telescope's optics are aligned properly, the defocused image of a moderately bright star should appear with a dark "donut hole" in the dead center. If the donut hole (which is actually the secondary mirror's shadow in the light path) isn't central, use an Allen wrench that ships with the telescope to adjust the secondary mirror until the dark hole lies centered in a ring of light. You adjust the secondary mirror using the three screws set in its housing, located in the middle of the scope's corrector plate.

The only hard part of the process is working in the dark with an Allen wrench. If you plan on tweaking alignment regularly, as I do every time, since I have to drive bumpy back roads to my favorite dark-sky site, you might consider replacing the Allen screws with some oversized hand knobs, available at most hardware stores. The knobs won't protrude beyond the edge of the secondary holder, yet are large enough to use in the dark without groping.

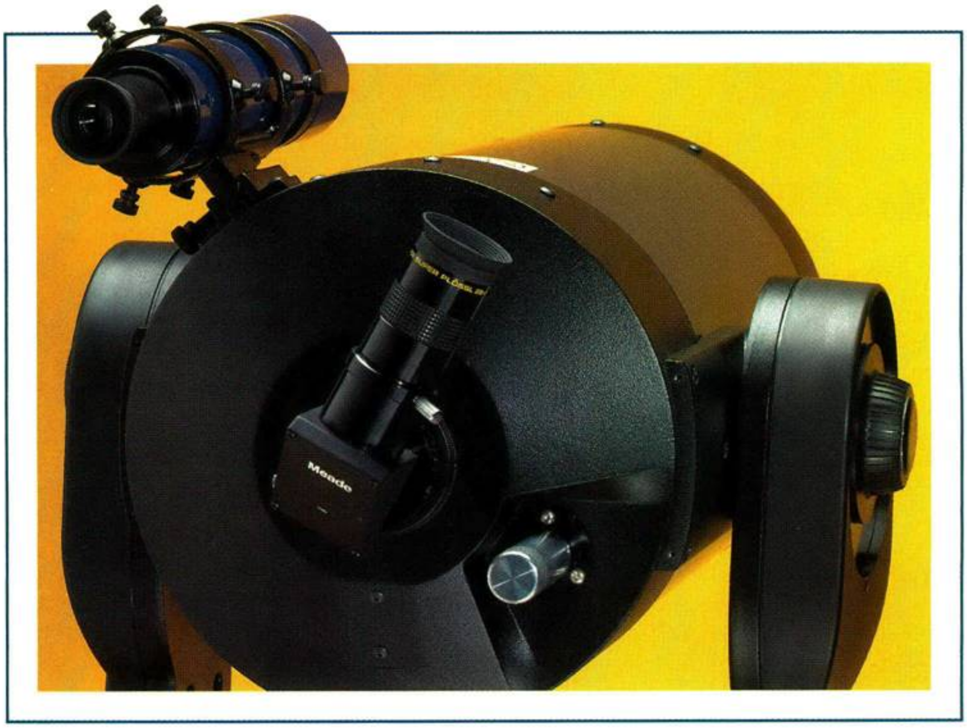
I typically test a scope for glare control by looking for faint stars as close as possible to the limb of a brightly lit Moon. I could easily see 3rd-magnitude stars as they emerged from behind the Moon's bright limb. The Moon itself offered lots of visual treats. Wrinkle ridges in Mare Imbrium came into sharp relief at 290x, as did the terraces of Copernicus and jumbled terrain to the south. The Moon's lit limb looked free of spurious color and focused to a knife edge.

Specifications

Aperture: 8"
Focal length: 2070mm
Focal ratio: f/10
Telescope weight: 31 pounds
Tripod weight: 20 pounds
Central Obstruction: 3" (37.5%)
Tube length: 16"
Accessories: 26mm Super Plössl eyepiece, 8x50 finder scope, 1.25-inch star diagonal, and hand controller
Typical "street price": $1,495

Contact information

Meade Instruments Corporation
6001 Oak Canyon,
Irvine, CA 92618
800-626-3233;
949-451-1450;
949-451-1460 (fax)
www.meade.com



Two-inch threaded rear cell accepts a 1.25-inch adapter, shown fitted with diagonal and eyepiece. A brushed-aluminum finish makes it easier to locate the focuser in subdued light.

The LX90 performed beautifully on splitting colorful and close double stars. Fifth-magnitude Xi Boötis, a nice double in Boötes, revealed its 7th-magnitude companion shining some 7" to the northwest. The colors in this duo were breathtaking. Antares is easy to split in an 8-inch. What makes it difficult to resolve sometimes is not the separation (3"), but the difference in brightness between the 1st-magnitude primary and its 7th-magnitude companion. The LX90 split it with ease and revealed the duo's nice orange-blue color contrast as well.

The scope's optics also checked out on Deneb in a star test: Images were identical on either side of focus, concentric and symmetrical. Deneb also came in handy for applying an exacting optical test: a Ronchi grating. This device alters light waves to profile the optics that focus the waves. The ideal image is round and composed of parallel bands of light. If the bands show distortions, the optics suffer from defects such as zonal errors or over- or under-correction. This is a brutal test; a mirror with the slightest flaw reveals "problem bands."

I slipped in an eyepiece from JSP Easytester that comes fitted with a Ronchi grating. From what I could tell, the optics in the LX90 were defect-free.

Schmidt-Cassegrain telescopes typically focus by moving the primary mirror back and forth as you twist the focusing knob. In some designs, this causes the image to shift. I noticed no such shift in the LX90. When I rapped the scope while viewing at high power, vibrations died out in less than two seconds. Meade sells vibration-suppression tripod foot pads that can cut this time by at least half.

Prowling the Deep Sky

An 8-inch telescope such as the LX90 is great for planets, but it also qualifies in my book as a bonafide deep-sky scope. When you cross the 8-inch aperture threshold, deep-sky objects go beyond mere blurs of light. Globular clusters become scattered fields of stars and galaxies begin to take on structure.

I had a blast scanning the star clusters of summer. Favorite, often overlooked, NGC obscurities such as globulars in Ophiuchus, Scutum, and Sagittarius resolved into tight groupings of stars. Early-morning sky previews of the galaxies of fall, scattered throughout Pegasus and Pisces, were a delight. Sculptor's NGC 253 showed itself to be a banked spiral galaxy wracked with knots of star-forming regions. Having Autostar at my fingertips easily tripled the number of targets I viewed in the space of a few hours. A key feature for experienced observers, you can observe more targets in a given time.

Meade bundles a 26mm Plössl eyepiece with the LX90. This gives a 52° apparent field of view, which was great on dark nebulae along the Milky Way. A good portion of each glowing lobe that composes the Veil Nebula in Cygnus fit nicely into the 26mm field.

The LX90 works best as a visual scope, but it can do astrophotography on bright targets like the Moon and planets. All you need is a T-adapter that hooks an SLR camera up to the telescope so it works like a 2070mm telephoto lens. A tele-extender, coupled with an eyepiece, lets you shoot higher-magnification views of the planets. But exposures can't run long, because the field rotates when you track the sky with an alt-az mounting.

For longer exposures I recommend converting the LX90 to an equatorial variant, using Meade's optional equatorial wedge. The Autostar system has modes that let it operate equatorially.

The LX90 embodies a 21st-century trend in amateur astronomy: the marriage of excellent optics with robust and proven computer technology. Go-to telescopes have matured and will remain a solid part of astronomy's future. For anyone looking for a fine Go-to telescope at a reasonable price, the LX90 is a good performer. A

John Shibley is a contributing editor of Astronomy *and a long-time observer and astrophotographer. He explores the sky from the Upper Peninsula of Michigan.*

PRODUCTS

Paramount ME Robotic Telescope System

Serious CCD imagers, survey astronomers, and traditional astrophotographers will be interested in Software Bisque's redesigned Paramount ME Robotic Telescope System. Virtually every component of the mount is custom-made to maximize strength and rigidity, while the weight remains a manageable 62 pounds.

Features include an equipment capacity of 125 pounds; periodic error less than 5 arcseconds; tracking for unguided exposures lasting 15 minutes or more; virtually zero backlash in both axes; mount-homing for quick start-up and consistent night-to-night performance; an OTA adapter for mounting any optical tube assembly; and Software Bisque's Observatory Control Suite. The system costs $10,000.

Software Bisque, 912 Twelfth Street, Golden, CO 80401; (800) 843-7599; website: www.bisque.com.

Paramount Pictures Presents *The Core*

After exposing Earth to alien attacks, asteroid impacts, perfect storms, and twisters, Hollywood is digging pretty deep to come up with its latest heart-pounding thriller. Literally. In Paramount Pictures' *The Core*, due out next month, an international team of scientists and government agents must somehow set Earth's iron core spinning again after it has mysteriously stopped. The consequences are dire — Earth's magnetic field has begun to unravel, and people have begun to drop like flies. Fortunately, for the last 20 years, a scientist has been developing a groundbreaking craft that can tunnel through Earth. A plan is hatched. "Terranauts" will travel to the core and detonate a nuclear device that will, with luck, save the world. While many liberties are taken with the science the movie is based on, *The Core* highlights the importance of the planet's innermost workings and should provide viewers a suspenseful journey to the center of Earth. Directed by Jon Amiel, the film stars Aaron Eckhart, Hilary Swank, Delroy Lindo, Stanley Tucci, DJ Qualls, Tcheky Karyo, Richard Jenkins, Bruce Greenwood, and Alfre Woodard.

BOOKS

Seeing in the Dark: How Backyard Stargazers Are Probing Deep Space and Guarding Earth From Interplanetary Peril

Timothy Ferris, 400 pages, Simon & Schuster, New York, 2002; ISBN 0–684–86579–3; hardcover, $26.

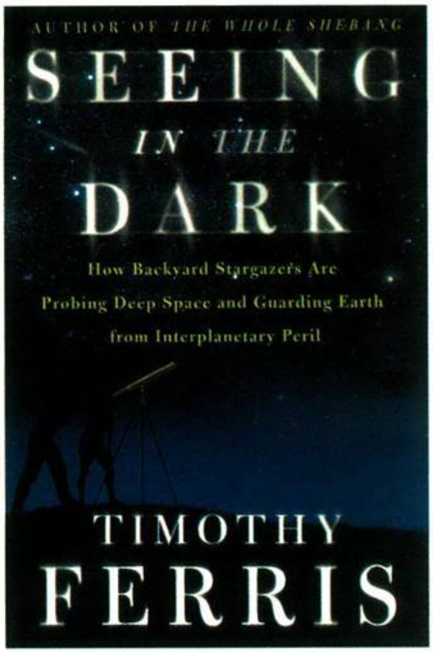
A revolution is sweeping through the world of amateur astronomy. A few decades ago, most amateurs happily scanned the heavens using relatively small instruments. They chipped away at the Messier list, and some managed to capture images of the brighter celestial objects on film.

Today, armed with giant Dobsonian telescopes and CCD cameras, advanced amateurs are doing professional-quality research and making significant contributions to the science of astronomy.

In his book *Seeing in the Dark*, prolific science writer Timothy Ferris eloquently documents this transformation while at the same time providing an introduction to the night sky. He draws on both his own and others' celestial experiences to explain how technology has vastly expanded the boundaries of the universe for backyard observers.

Ferris reminds us that many of the great astronomers of the past were amateurs, whose work wasn't overshadowed by professionals until the early 20th century. The pros still have access to much larger instruments, but an amateur 20-inch telescope equipped with a CCD camera is a formidable weapon for unlocking cosmic secrets. Today, amateurs can even photograph the heavens remotely using robotic telescopes coupled to the Internet.

Unlike many professionals who must vie for precious time on large scopes, amateur astronomers have the time to conduct long-term observing projects. They document weather events on the planets, discover comets and supernovae, monitor variable stars and sunspots, and search for unknown asteroids. Amateurs also record breathtaking images of celestial objects that rival those made with the world's largest telescopes a few decades ago. The quality of their work has sometimes resulted in fruitful collaborations with professional astronomers.


AUTHOR OF THE WHOLE SHEBANG
SEEING
IN THE
DARK
How Backyard Stargazers Are
Probing Deep Space and Guarding Earth
from Interplanetary Peril
TIMOTHY
FERRIS

Throughout the book, Ferris introduces us to some of today's amateur superstars. Readers meet comet hunter David Levy, astronomy popularizer Patrick Moore, eagle-eyed stargazers Barbara Wilson and Stephen O'Meara, and the amazing astrophotographers Jack Newton and Don Parker. Readers can stand with Ferris at the eyepiece of Lowell Observatory's historic 24-inch refractor and even chat with Brian May from the rock band Queen.

The thrill of discovery comes vividly alive in Ferris's story about science teacher Hughes Pack, who fought to contain his excitement as he watched three of his students discover a trans-Neptunian object (a body whose orbit lies beyond Neptune). They made the find while examining CCD images from the University of California, Berkeley's "Hands-On Universe" project.

A couple of numerical errors have crept into the book. Earth's rotational velocity is listed as 24,000 mph when it is actually about 1,000 mph at the equator. Similarly, Jupiter's stated rotational velocity is double the correct value.

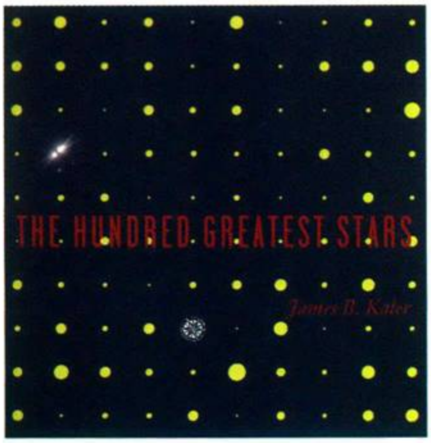
Seeing in the Dark celebrates amateur astronomy and will inspire novices and experienced stargazers alike. As I closed the book after reading the final page, my mind lingered in some faraway place in the universe. *Seeing in the Dark* is one of the best astronomy books I've ever read. — *Richard Sanderson is curator of physical science at the Springfield Science Museum in Springfield, Massachusetts and is a former president of the Springfield Stars Club.*

The Hundred Greatest Stars

James B. Kaler, 213 pages, Copernicus, New York, 2002; ISBN 0–3879–5436–8; hardcover, $32.50.

Gaze up on any clear, dark night and you can see the sky is filled with thousands of stars. Enthralling countless generations, these celestial beacons form seemingly unchanging patterns, but the stars themselves are bewilderingly varied — some are incredibly bright, while others are barely visible. Every star is an individual with its own unique place in the cosmos.

This stellar grandeur is perfectly captured in James Kaler's lavishly illustrated and expertly written volume, *The Hundred Greatest Stars.* A great popularizer of astronomy and a professor at the University of Illinois, Kaler conveys the glory of these nuclear powerhouses with scientific descriptions and personal opinions. His eclectic choices are based on each star's location, history, uniqueness, and sheer beauty. Indeed, this collection spans stars' extraordinary diversity.



Beginning with an introduction designed for the novice stargazer, the author discusses the frequently daunting astronomical terminology associated with stellar evolution. Readers are then guided through an alphabetical listing of stars, beginning with Acrux and ending with ZZ Ceti. The author devotes two full pages to each star, detailing what makes it special on one page and providing a color snapshot or illustration on the other.

As with stars on the silver screen, some members of Kaler's glitterati are more glamorous than others. "Superstars" include Arcturus, Betelgeuse, and Sirius, while lesser-known figures include EG 129, a diminutive white dwarf with a magnetic field more than a billion times that of Earth.

Kaler's deep love and enthusiasm for the stars shines through on every page. Even though the book is dedicated to the amateur astronomy community, it will surely appeal to anyone who has ever looked at the sky with a sense of curiosity and wonder. — *Andrew S. Fazekas writes an astronomy column and regularly conducts educational workshops in Montreal.*

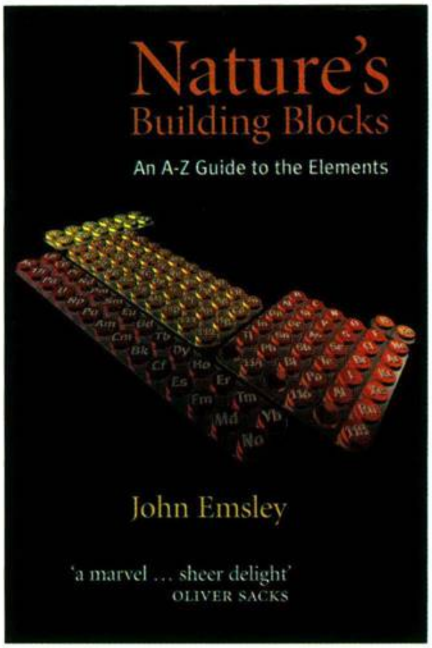
Nature's Building Blocks: An A-Z Guide to the Elements

John Emsley, 538 pages, Oxford University Press, New York, 2002; ISBN 0–198–50341–5; hardcover, $29.95.

Think back to your first high school chemistry class. Do you remember that big periodic chart of the elements hanging above the blackboard? I was 16 years old and hadn't the foggiest idea why gold should be "Au," mercury should be "Hg," and potassium should be "K." The chromium on my '53 Chevy's bumper was "Cr." That made sense, but the rest didn't. And our science teacher, bless him, forgot to explain.

Well, after reading *Nature's Building Blocks*, I finally understand. Now I know that Au comes from the Latin word *aurum*; Hg derives from the Latin *hydragyrum,* meaning liquid silver; and K stems from *kalium*, an ancient Latin term for potash (which possibly descended from an Arabic word meaning alkali).

And it took me only three minutes to look all that up in this intriguing dictionary about what makes up our world — and our universe. Mr. Emsley, thank



you for filling in the blanks Mr. X ignored so many years ago.

This book is much more than a reference text for working chemists and physicists, although they, too, would probably learn some fascinating tidbits passed over in grad school. For example: Did you realize that habitual tea drinkers get a sizeable dose of aluminum in their bodies because tea bushes absorb a lot of "Al" from the alum used as fertilizer on tea plantations? Or that Europeans spell the element "aluminium" (pronounced al-yoo-min-i-uhm)? The American Chemical Society argued this issue in 1925 and just decided to be different. Damn Yankees!

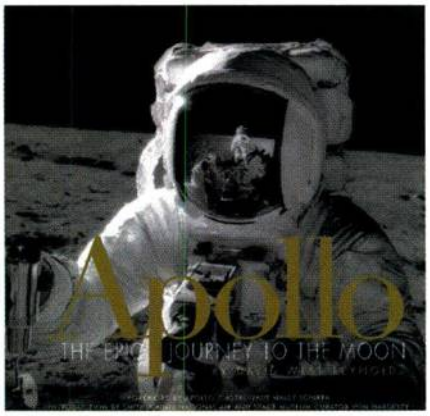
Can you believe that when we look up at the brilliant nighttime stars, virtually everything we see is gas? The visible universe itself is 88 percent hydrogen, 11 percent helium, and only 1 percent everything else. Our own Sun is 94 percent "H," 6 percent "He," and less than 0.2 percent other elements. It's a wonder anything solid exists anywhere.

The book is in alphabetical order with a section on each of the currently known elements, so finding what you're looking for is easy. Each section concludes with an "Element of Surprise," featuring tidbits about the impact of that element on our everyday lives.

But Emsley sometimes confuses. "Actinium is never encountered outside nuclear facilities or research laboratories," he writes. But on the following page he says, "Actinium occurs naturally in the Earth's crust." I spotted several such apparent contradictions.

Of particular interest to astronomers and space enthusiasts is the entry on plutonium, the politically controversial and often misunderstood radioactive element used to trigger hydrogen bombs. Most people don't understand that "Pu" comes in different forms. One gram of the highly fissionable Pu239 isotope in a nuclear reactor could equal the energy production of a ton of oil. But the less fissionable Pu238 isotope is often used as an electricity-producing heat source in deep-space probes. All those wonderful closeup photos of Jupiter, Saturn, Uranus, and Neptune and their moons come to us courtesy of Pu238. Someday, plutonium might help us visualize its namesake, the outer planet Pluto.

Emsley closes with a thought-provoking quip. If we ever encounter an alien civilization, he says, they will certainly recognize our periodic chart of the elements because we're all made out of the same kind of stuff. Now if my southern Missouri high school chemistry teacher had led off with that, I surely would have paid more attention to that thing on the wall above the blackboard. — *Nick Nichols is the retired news media relations manager at the Idaho National Engineering and Environmental Laboratory in Idaho Falls.*



Apollo: The Epic Journey To The Moon

David West Reynolds, 272 pages, Harcourt, New York, 2002; ISBN 0-1510-0964-3; hardcover, $35.

Thirty years after the end of the Apollo program, readers may wonder why new books about the project keep appearing. This book is one reason — aimed at a generation for whom the Moon landings are "ancient history," it provides new insights, images, and assessments with the wisdom of hindsight.

In an engaging, unified narrative, Reynolds explains how the program's engineering challenges were overcome, how the space vehicles were built and flown, and what the astronauts experienced along the way.

Of the more than 400 fine illustrations, the standouts are of flight profiles during launch and landing (both on the Moon and on Earth). They look three-dimensional and pop out of the page with a depth and clarity I've never seen before. The combination of a large-format book with many two-page photo spreads is a visual delight for readers who encounter the subject for the first time or the hundredth.

Reynolds's words are often stirring. "Without a human proxy, space exploration can accomplish good science but achieves limited public engagement," he writes. "There is something irreplaceably inspiring about a human presence on the frontier of exploration." Regarding Neil Armstrong, the civilian commander of the first landing mission, he writes: "His personal qualities would shape the character of Apollo 11, making this a mission that bore the mantle of history with soft-spoken honor rather than superficial humor or brash ego."

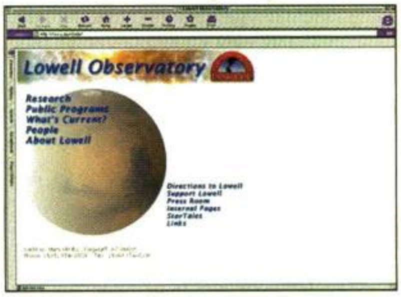
Reynolds basically portrays the Apollo program as having been accomplished by German rocket expert Wernher von Braun and a few associates (there are 20 photographs of von Braun, compared to one or two each for all the others). He mentions that von Braun was "heartbroken" that his rockets were used against civilians in World War II but does not tell how many people were killed. And his assertion that by the late 1960s von Braun had solved "the greatest technological problems" of manned flight to Mars is inflated — these problems are only now being recognized and worked out. Reynolds is thrilled with the vision that President Kennedy brought to the program, but clearly despises Republican presidents Eisenhower and Nixon, as well as current projects such as the shuttle and space station, which he says "lack purpose."

The text stops short of specifics in some areas. What was the cause of death of the Apollo 1 astronauts? Which boot did Armstrong place first on the Moon? (It was the left one, by the way.) Actual errors include mislabeled captions as well as more serious offenses, such as the mention of a Soviet rocket failure in July 1969 that created a fireball that killed more than 100 people. In fact, the fatalities occurred during a military missile test a decade earlier.

With the caveat that mistakes may lurk in some details, the "big picture" of the Apollo program remains reliably informative and refreshingly inspirational. — *Jim Oberg is a lifelong amateur astronomer, a veteran of 22 years at Mission Control in Houston, and an active writer and consultant on spaceflight.*

The Webweaver Picks

by Richard J. Bartlett

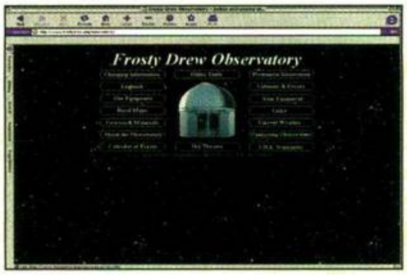


Last summer we looked through the eyepieces of observatories in Europe and the Southern Hemisphere. This month, join me for a virtual trip to some observatories in the United States.

We'll start at the Whitin Observatory in Wellesley, Massachusetts. Located on the Wellesley College campus, it's home to a 24-inch reflector, a 12-inch refractor, a spectrohelioscope, and a small radio telescope. In addition, a 6-inch refractor and six 8-inch Schmidt-Cassegrains are available for use on public nights. If you live nearby, check out www.wellesley.edu/Astronomy for information about their courses.

Next, we'll head south for 90 miles to Charlestown, Rhode Island. There we'll find the pleasantly named Frosty Drew Observatory in Ninigret Park. Funded by donations, open evenings take place every Friday. You're welcome to bring your own equipment or to use the on-site 16-inch reflector. Astronomical courses, essays, and log books are posted online at www.frostydrew.org/observatory.

Heading southwest, we'll find the Astrophysical Observatory at the College of Staten Island in New York. It's open every Monday evening at 8, giving the public three hours of observing time with the 16-inch Schmidt-Cassegrain (http://supernova7.apsc.csi.cuny.edu/home.html).



Another 550 miles away is the Perkins Observatory in Columbus, Ohio. If their website (www.perkins-observatory.org) is any indication, the observatory folks love sharing astronomy with visitors. It's open to the public Friday and Saturday evenings with a monthly lecture on a Thursday. Learn more about the observatory and staff (including the cat) online, where you can also find essays, sky charts, and activities.

It's nearly 850 miles to Wichita, Kansas, and the Lake Afton Public Observatory. The doors are open to the public between 7:30 and 10:00 Friday and Saturday evenings.

Check for upcoming events, teacher resources, binocular sky maps, and back issues of *Skylights*, the observatory's newsletter, at http://webs.wichita.edu/lapo.

Our next stop is Boulder, Colorado, where a friendly team of enthusiasts at the Sommers-Bausch Observatory will show us the universe on a clear Friday night. Check the program, which varies weekly, at http://lyra.colorado.edu/sbo/sbo.html. If the 24-inch Cassegrain isn't available, a number of smaller scopes are ready for use.

Los Angeles's Griffith Observatory is next on our virtual tour, although be aware that real-life tourists will only find a temporary planetarium at Griffith Park, as the observatory is closed for renovations until 2005. Lucky visitors might be able to catch a star party with the Los Angeles Sidewalk Astronomers in a corner of the park. To follow the progress of the renovations, go to www.griffithobs.org.

Looping back east, we visit the Lowell Observatory in Flagstaff, Arizona. Founded in 1894 by Percival Lowell, it houses the 24-inch Clark refractor used by Lowell himself. It's also where Clyde Tombaugh discovered Pluto in 1930. Check out the observatory's history and public programs at www.lowell.edu.

In Fort Davis, Texas, we'll find the McDonald Observatory. Part of the University of Texas and located in the dark-sky environment of the Davis Mountains, the facilities house a variety of instruments. We won't get the chance to peer through the 9.2-meter Hobby-Eberly telescope because it is used only for research, but we can tag along on daily tours, workshops, and star parties every Tuesday, Friday, and Saturday. For further details, see http://mcdonaldobservatory.org.

Griffith Observatory

About 850 miles east is Baton Rouge, Louisiana, and the Highland Road Park Observatory. Using their 20-inch Ritchey-Chrétien telescope and CCD camera, researchers have discovered an incredible 55 asteroids since 1998. Times and locations to see these are available at www.bro.lsu.edu/hrpo. You'll also find details of their Friday night and Saturday morning workshops.

Finally, we'll take a 500-mile trek to the Valdosta State University observatory in Georgia. It's home to a 16-inch Schmidt-Cassegrain and several smaller scopes. Public evenings are every Thursday at 8. Start with a planetarium show before heading over to the observatory. For more information, visit www.valdosta.peachnet.edu/vsu/dept/cas/phy/astro/index.htm.

This is the last stop on our road trip and, unfortunately, this is also the last Webweaver Picks. I hope you've enjoyed reading the columns as much as I've enjoyed writing them. If you'd like to contact me, you can still do so through my StarLore website at www.starlore.net.

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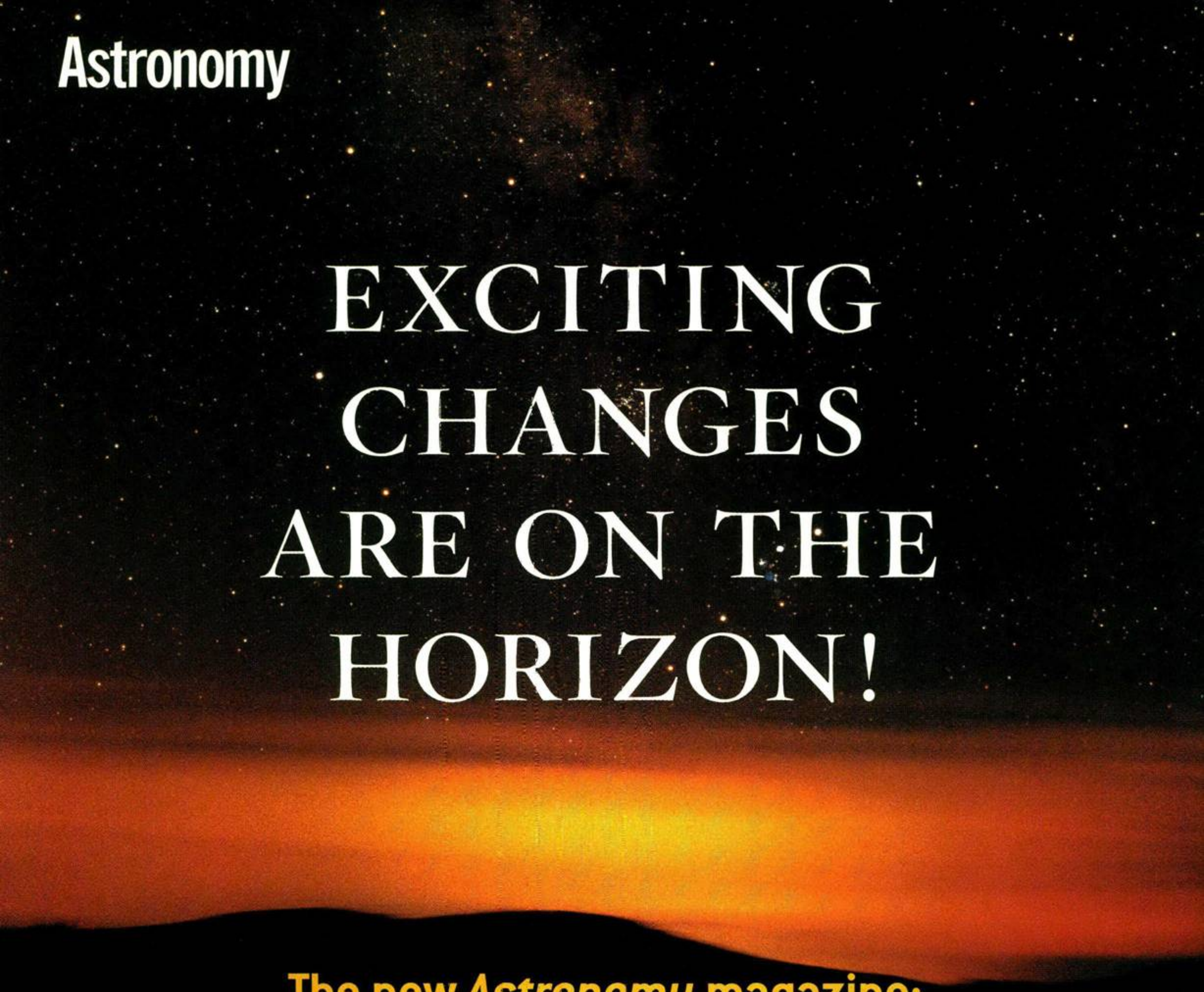

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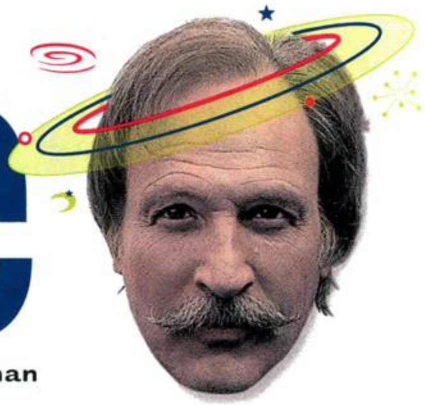

by Bob Berman

And the Best Constellation is...

If a judge put you under house arrest, like poor Galileo, with a window that faced only one particular direction, which way would you prefer to look? North toward the Dippers or south toward Scorpius and Fomalhaut?

Don't say all the constellations are great. They're not. It's like asking a parent, "Which of your kids is your favorite?" Those who are politically correct say, "I love them all the same." Baloney! Parents often have one smiley kid who snuggles up to them while the other's a snarling brat. Of course we have favorites. Favorite political parties, favorite restaurants, favorite cars, favorite jokes. And favorite constellations.

If you need help choosing, start by first eliminating the losers. Of the 88 constellations, half can be crossed off from the get-go. Leo Minor, whack, that one goes first. Sagitta the Arrow. Camelopardalis the Giraffe, which is circumpolar and therefore stares at you every clear night of your life — IF you can even find the sonofagun.

How did these ever get started? Who could possibly have visualized a zoo animal in those random 5th magnitude stars? We actually know the answer. The villain was a Dutch theologian and cartographer named Petrus Plancius, and the crime happened 405 years ago. As in most historical novels, we'll have to fill in the details. Petrus, whom we can safely assume was an alcoholic, kept insisting he saw a giraffe in the sky until his friends decided to humor him. "Sure, there's a giraffe there, we can all see it, now go to bed." But then the rumor spread that a bunch of guys all observed the same mammal in the sky, and no one wanted to be left outside the club. Result: We're stuck with it.

Musca the Fly, there's another one. With all the cool creatures like dolphins, lions, golden retrievers, or even house cats that might have been immortalized in the heavens, who decided on an annoying, disease-carrying insect? This one may have originated way back in Babylonia; no one's quite sure. Small wonder that country vanished, only to be replaced in that same site by Saddam Hussein. Must be the water.

Sextans, Equuleus, Sculptor, Mensa, Grus — the forgettable patterns are easy to spot because they're hard to spot. No bright stars. No recognizable shape. No brilliant deep-sky wonders. And these same criteria can be turned the other way to help pick the sky's aces.

> **"Sure, there's a giraffe there, we can all see it, now go to bed."**

If we base our selection on how well a constellation resembles what it's supposed to, then only two could win first place — Orion and Scorpius. Orion really does look like a hunter. Well, not necessarily a hunter. Simply a person of some sort, someone who wears a belt, but it could just as easily have been a judo instructor, a sumo wrestler, or an accountant. They all wear belts. But a hunter is good enough.

Scorpius really does resemble a scorpion; in southern places where its magnificent tail ascends high enough to be seen well, it would probably take the trophy as most spectacular constellation, especially with all those blue stars contrasting so vividly with the single blazing red Antares that denotes its heart. Yes, I'd vote for Scorpius. Orion is very cool, too, even if he has an unrealistically feeble head. (But then, so do some of the hunters in my area.)

Or do we instead choose the constellation with the greatest concentrated brilliance? In that case the winner is the Southern Cross. And when Crux stands upright, it even points straight down to the South Pole. Very nice indeed.

The largest constellation might make the cut, but there's no clear standout. Instead, the sky presents an odd virtual three-way tie for winner. Hydra takes up 1,303 square degrees, just six more than Virgo, which in turn has just 15 more than Ursa Major. (This trio occupies fully 10 percent of the sky! By contrast, the three smallest — Crux, Equuleus, and Sagitta — together inhabit just half of one percent).

Some might argue that the prize should go to the constellation with heaven's most famous star. If so, the winner is either Ursa Minor (home to the North Star) or Canis Major (Sirius, the brightest star). The latter's crammed with cultural lore, but its competitor, Polaris, guided slaves toward liberation — they'd follow the North Star. So the Little Dipper represented freedom, not a bad concept at all.

The most famous asterism is the Big Dipper, part of the Great Bear. That would make it a finalist, too. Centaurus deserves consideration as well: Its sprawling boundaries contain not only the stars nearest Earth, but also Omega Centauri, the most spectacular telescopic object of all. Alas, it's low or invisible from the U.S. and Canada, and probably loses out simply because of its refusal to walk the runway for our consideration.

Then there are the zodiacal ones, which host the Sun, Moon, and planets and have therefore topped every culture's "favorites" list throughout history. Of these, Gemini climbs highest up and is also the only one to blaze with two first magnitude stars. But Sagittarius can't be ruled out since the center of our galaxy, along with the nearest massive black hole, lies within its borders. All the night's stars revolve around that spot every 240 million years. Powerful stuff.

Virgo is where the Sun sits at the autumn equinox, but more importantly it contains the most bright galaxies. It's the downtown hub, the Times Square of this entire section of the universe. Even our own galaxy is just an outlying member of the Virgo Cluster, centered in this constellation. An excellent reason to make Virgo top dog.

Anyway, you see the problem. Too many categories.

There's even more when one includes telescope targets. Which, for example, contains the most or the best deep-space wonders? Little Lyra with its Ring Nebula and double-double star Epsilon Lyrae? Cygnus, housing the night's most colorful binary (Albireo) plus the incomparable Veil Nebula, along with the only black hole viewable through most backyard instruments? What about two otherwise dull constellations, Coma Berenices and Canes Venatici, which resemble a princess's hair and a pair of hunting dogs the way I resemble Britney Spears, but which nonetheless have two of the finest galaxies? Or Andromeda, solely for possessing the nearest and brightest spiral?

The problem is the sky's wonders are too democratically sprinkled around. Maybe that's why, even in our superlative-loving culture, you rarely hear of "the best constellation." But we're open-minded. Make your case. What's *your* "top ten" list?

We'll announce the votes later this year. The most compelling entry will be quoted here, and the winner also gets to rename Camelopardalis. Sorry, but I've met giraffes and you, sir, are no giraffe. ■

Bob Berman's "Strange Universe" column appears monthly in Astronomy.

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Beginner's sky

Cosmic adventures for the neophyte astronomer. by Glenn Chaple

"Mirror, Mirror, on the wall
What's the brightest star of all?"

"The brightest star, oh brainless one,
Is the daytime star we call the Sun,
But if you mean the stars at night,
'Tis Sirius casts the brightest light."

"Brainless one"? I ask an honest question and get insulted by a piece of glass. Then again, perhaps my question wasn't worded so well — it's easy to forget that our Sun is actually a star. But how do astronomers rate star brightness?

The answer is magnitude, a scale that dates back more than 2,000 years to the Greek astronomer Hipparchus. Rather than describe stars as "bright" or "dim," Hipparchus grouped them into six categories. The handful that outshone all others was designated as 1st magnitude. Brightness groupings continued all the way to 6th magnitude, the faintest stars the human eye can discern on a dark, moonless night.

Modern astronomers expanded and refined Hipparchus's magnitude system to include negative numbers for really bright objects, and decimal fractions for greater precision. Sirius, the brightest nighttime star, shines at magnitude –1.4, while the Sun boasts a magnitude of –26.7!

So the Sun is the brightest star in the universe, right? Wrong! The figures we quoted for Sirius and the Sun refer only to how bright they appear from Earth — their apparent magnitude. The Sun outshines Sirius because it's thousands of times closer. Which star is truly brighter? If we had godlike powers, we could place the Sun and Sirius side by side for comparison. This is actually possible mathematically — knowing the apparent magnitude of a star and its distance from Earth, we can calculate how bright it would appear at any location in space.

Astronomers decided that a good distance for this absolute magnitude would be 10 parsecs (32.6 light-years). Since Sirius is just 8.6 light-years away, a move to 32.6 light-years would dim the star to magnitude 1.4. From that distance, the Sun would be a feeble magnitude 4.8, dimly visible in dark skies.

If we could place all stars at this absolute magnitude distance, many would outshine both Sirius and the Sun. Rigel, in Orion, shines at apparent magnitude 0.1, much fainter than Sirius. But Rigel is a whopping 900 light-years away. Move this star to a distance of 32.6 light-years, and it would be magnitude –7.1 — a stellar beacon bright enough to cast a shadow on the ground at night and be visible during the day! Even mighty Rigel isn't the galaxy's most luminous star. Astronomers are currently studying several candidates. One, the "Pistol Star," located near the center of our galaxy, may be 15 times brighter than Rigel — and 10 million times brighter than the Sun!

So, Magic Mirror, neither the Sun nor Sirius is the brightest star of all. Perhaps an apology is in order?

The Magnitude Challenge

Last month, we looked at the bright stars in and around the constellation Orion. Sirius, Rigel, Aldebaran, Capella, Castor, Pollux, and Procyon form a huge, football-shaped pattern known as the Winter Hexagon. All are 1st-magnitude stars, except for Castor, which misses by a heartbeat — er, photon. Throw in Betelgeuse, and we have a truly impressive winter array — one-third of the 21 officially recognized 1st-magnitude stars.

Since we've been talking about stellar magnitudes, see how well you can judge the brightness of some prominent Hexagon stars (we'll keep things simple by comparing stars to one another instead of estimating magnitudes). Try your luck with the following questions (turn the page upside down for the answers). Use the photograph to locate the stars. Good luck!

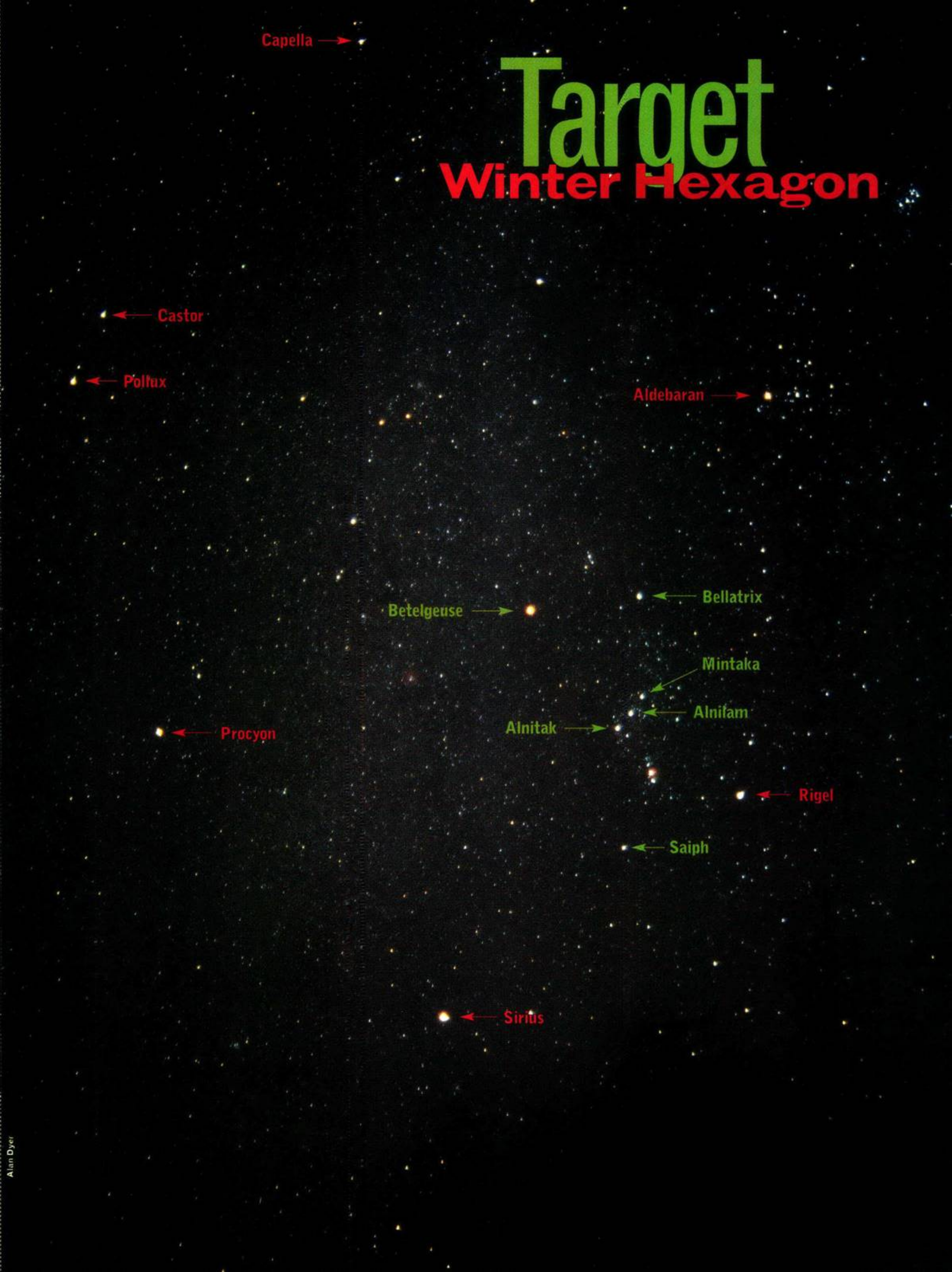
1. In each of the following pairs of luminous stars, which star looks brighter?
   Capella or Procyon
   Betelgeuse or Aldebaran
   Pollux or Rigel
2. Feeling brave? Try ranking the six stars above, from brightest to faintest.
3. The three stars in Orion's belt are 2nd-magnitude stars. But one is slightly dimmer than the others. Is it Alnitak, Alnilam, or Mintaka?
4. Betelgeuse and Rigel are at opposite ends of the rectangle that outlines the Hunter's body. The remaining stars, Saiph and Bellatrix, are 2nd magnitude. Which of these is brighter?

Saturn certainly adds a touch of dazzle to the Winter Hexagon. But have you noticed a really bright "star" to the east (left) of the Hexagon? That's Saturn's "big brother," Jupiter. Next month, we'll pay a visit to these solar system giants. Clear skies!

Glenn Chaple teaches science in Townsend, Massachusetts.

ANSWERS: 1. Capella; Betelgeuse; Rigel 2. Capella, Rigel, Procyon, Betelgeuse, Aldebaran, Pollux 3. Mintaka 4. Bellatrix

Target
Winter Hexagon


Capella
Castor
Pollux
Aldebaran
Bellatrix
Betelgeuse
Mintaka
Alnilam
Alnitak
Procyon
Rigel
Saiph
Sirius

cut along dotted line

Alan Dyer

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Astronomy's Rich Talcott will help lead this expedition of aurora watchers.

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Marvin Nauman

An aurora shines and a meteor sails above the lodges at Chena Hot Springs, Alaska.

JANUARY 16
How Stars Are Made

Chabot Space and Science Center, Oakland, California. Part of the Distinguished Lecture Series, this talk will be led by Steven Stahler of the University of California, Berkeley. For more information, visit Chabot's website, www.chabotspace.org/visit/calendar/.

JANUARY 25–JUNE 15
Little Bear's Wonderful Journey

Montreal Planetarium, Montreal. Oriented for young children and their parents, this planetarium show will highlight the daytime and nighttime skies through a musical presentation. For more information, visit the planetarium's website, www.planetarium.montreal.qc.ca/.

JANUARY 29–FEBRUARY 2
Orange Blossom Special Star Party

Hickory Hill Observing Complex, near Brooksville, Florida. This event is sponsored by the St. Petersburg Astronomy Club. The star party will feature astronomy lectures, great observing (solar and nighttime), a swap table, door prizes, youth program, and a music jam session. For more information, contact Dennis or Ellen Farr, 19309 Eastbrook Dr., Odessa, FL 33556; phone, 813–792–0721; e-mail, dnefarr@aol.com; website, http://home1.gte.net/hoffmanc/.

FEBRUARY 1
Benjamin Banneker

Adler Planetarium, Chicago. You can learn more about Benjamin Banneker, 18th century scientist and astronomer, when the Adler presents the kickoff to African-American Heritage Month activities. From 11 A.M. to 3 P.M., you can make your own Banneker sky observer's almanac to use at home to view the Sun and Moon. SPIRITS drum and masquerade society performs a thrilling African musical performance at 1:15 P.M. Benjamin Banneker (storyteller/actor Oba William King) will also be present at 2:15 P.M. to tell stories about his life and experiences in the late 18th century. For more information, visit the Adler website, www.adlerplanetarium.org.

FEBRUARY 3–8
Winter Star Party

Wesumkee, West Summerland Key, Florida Keys, Florida. Sponsored by the Southern Cross Astronomical Society. Located in one of the southernmost dark sites in the United States, stargazers have ample time to stargaze during 12-hour viewing sessions. For more information, contact Lucille or Fred Heinrich at 386–362–5995; fax, 386–362–5995; e-mail, heinrich1@alltel.net; or visit the SCAS website, www.scas.org/wsp.html.

FEBRUARY 7–9
Impact Cratering: Bridging the Gap Between Modeling and Observations

Lunar and Planetary Institute, Houston. The purpose of this workshop is to discuss how physical observations of craters can be combined with the results from simulated impact models for a better understanding of the impact cratering process. For more information, visit the LPI website, www.lpi.usra.edu/meetings/impact2003/.

FEBRUARY 8
Totality Day

Open University, Milton Keynes, United Kingdom. Beginning at 8 A.M., this is a one-day event featuring lectures concerning solar eclipses, primarily the total solar eclipse of 2003. The cost for Totality Day is £3/$4.65. For more information, e-mail, solareclipsewebpages@btopenworld.com; website, http://solareclipsewebpages.users.btopenworld.com.

FEBRUARY 13–18

American Association for the Advancement of Science Annual Meeting

Denver, Colorado. Scientific sessions, business meetings, and special events will be held at the Colorado Convention Center, Denver Marriott City Center, Hyatt Regency Downtown Denver, and Holiday Inn Downtown Denver. For more information, contact the AAAS Meetings Department, 1200 New York Avenue, NW, Washington, DC 20005; phone, 202–326–6450; e-mail, aaas-meeting@aaas.org; website, www.aaas.org/meetings/MPE.shtml.

FEBRUARY 27–MARCH 2

Mid-Florida Stargaze

Fisheating Creek Campground, Glades County, Florida. The Astronomical Society of Palm Beach will host this event. Observe in a friendly atmosphere away from city lights, high winds, and salt spray of the ocean. February is still the dry season in southern Florida. For more information, e-mail stargaze@palmbeachastro.org; mail the ASPB at P.O. Box 19652, West Palm Beach, FL 33416; website, http://palmbeachastro.org/.

MARCH 8

Wagman Winterfest

Nicholas E. Wagman Observatory, near Russellton, Pennsylvania. Sponsored by the Amateur Astronomers Association of Pittsburgh, this event begins at 4 P.M. For more information, visit the AAAP website, www.3ap.org.

MARCH 17–21

Lunar and Planetary Science Conference

Johnson Space Center, Texas. This conference brings together international specialists in petrology, geochemistry, geophysics, geology, and astronomy to present the latest results of research in planetary science. For more information, visit LPSC's website, www.lpi.usra.edu/meetings/lpsc2003/. ▣

CONTACT

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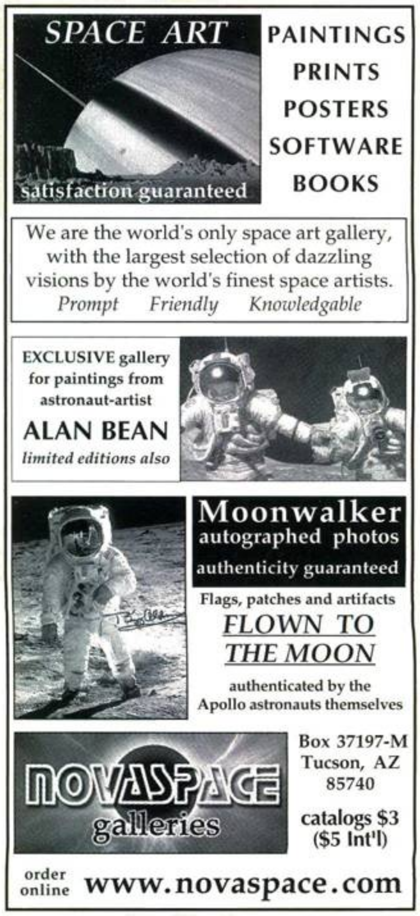

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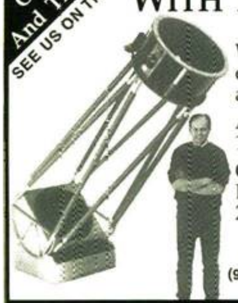

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Ten days, September 2003

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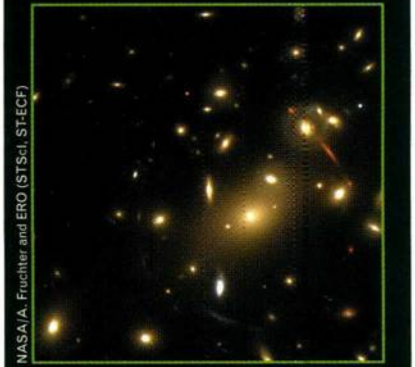

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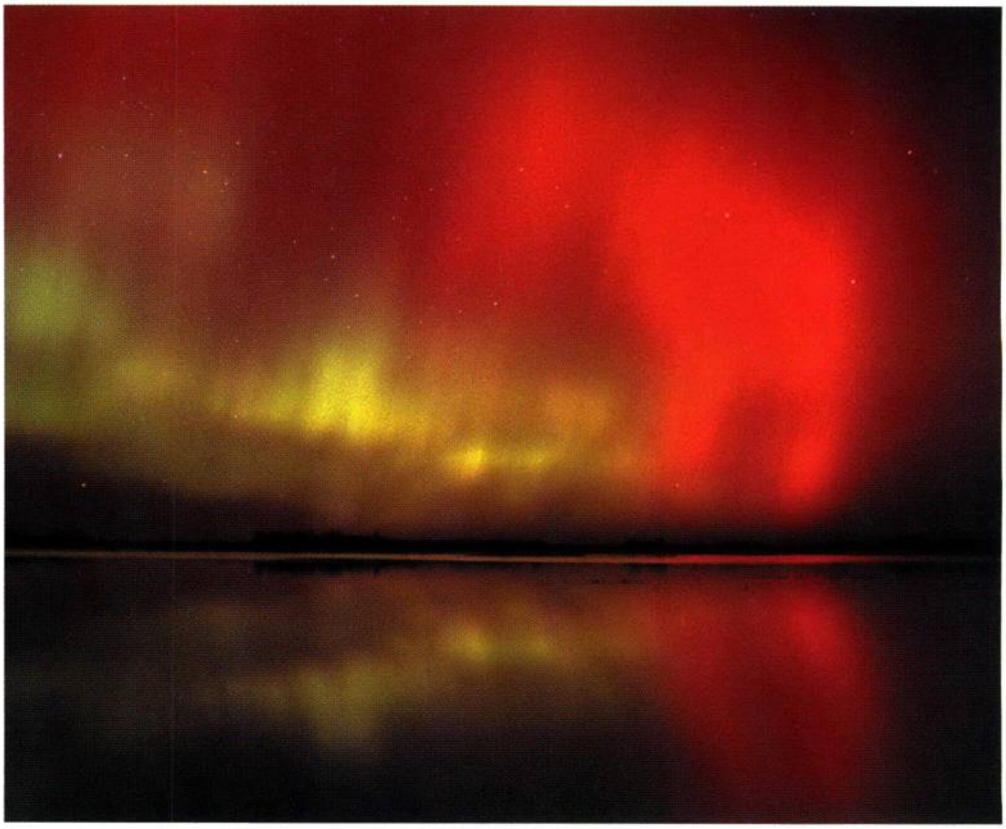
AN APOLLO 13 ADVENTURE

Finding the Way Home

In the spring of 1970, Apollo 13 was about to be launched, and I was looking forward to tracking it using the 24-inch telescope at Pine Mountain Observatory in the Oregon desert highlands. Members of the Portland Astronomical Society and students at Portland State University had observed Apollo spacecraft traveling to and from the Moon for some time. With the Apollo 12 mission, fellow student Dick Sears and I started a regular observing team. High school student and expert variable-star observer Jerry Mishler was our "calibrated" eyeball, because the phenomenon was too fleeting for film. After leaving Earth's orbit, Apollo appeared no brighter than a 4th magnitude star, usually much dimmer. Brightness could change rapidly due to reflections from the spacecraft and the venting of waste liquids and surplus fuel.

For the outgoing leg of the Apollo 13 mission, we experimented with a '50s military surplus television camera, but results were disappointing. So it was back to our variable-star astronomer and the light sensitivity provided by natural adaptation.

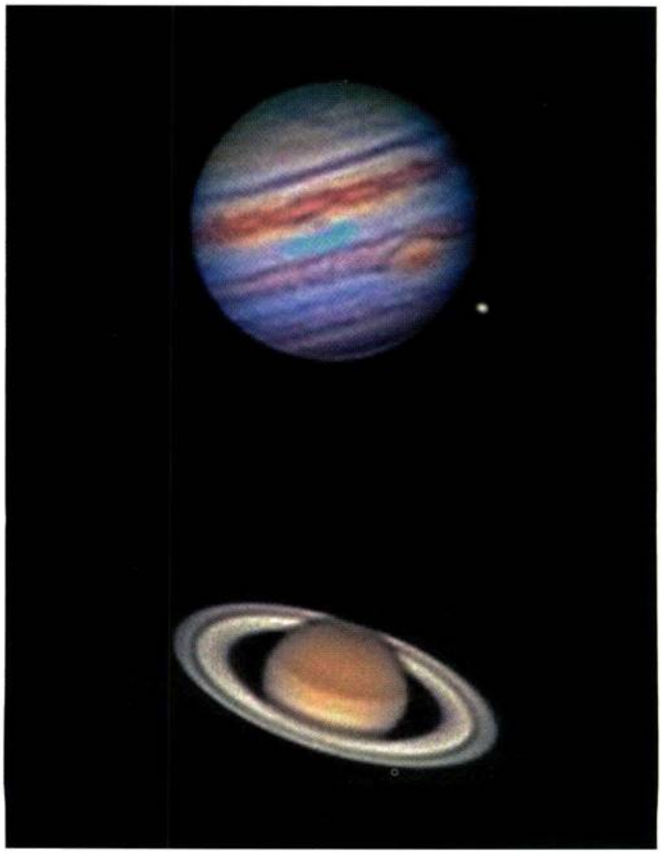
Back in Portland, an urgent communication from Dr. Bill McLaughlin of the Bellcomm Corporation and the Smithsonian told us to return to the observatory earlier than expected. There had been an explosion onboard Apollo 13. With the



▲ **Wisconsin Aurora**

CHRIS VEN HAUS

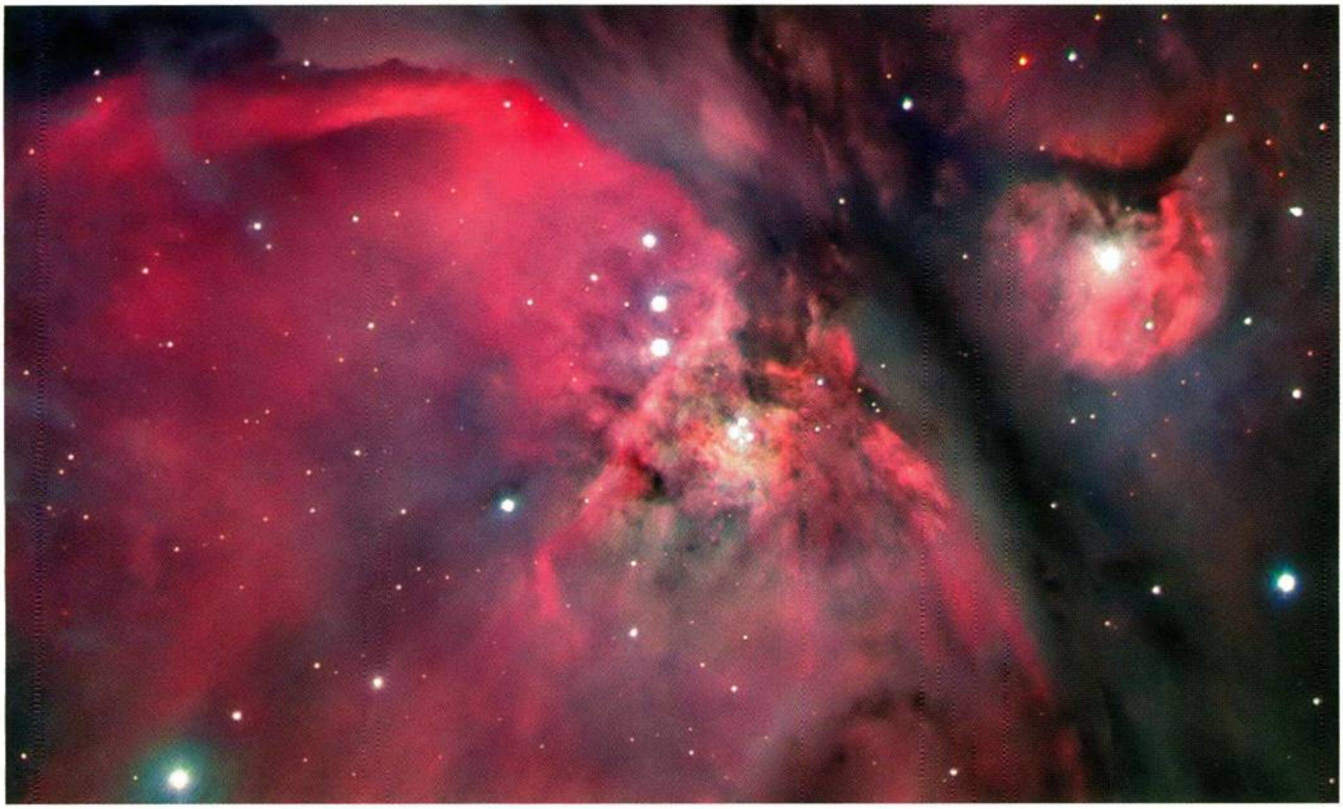
(35mm lens at f/2, Fuji Provia 400 film, taken October 28, 2001)



◀ **Jupiter, Io, and Saturn**

STATHIS KALYVAS

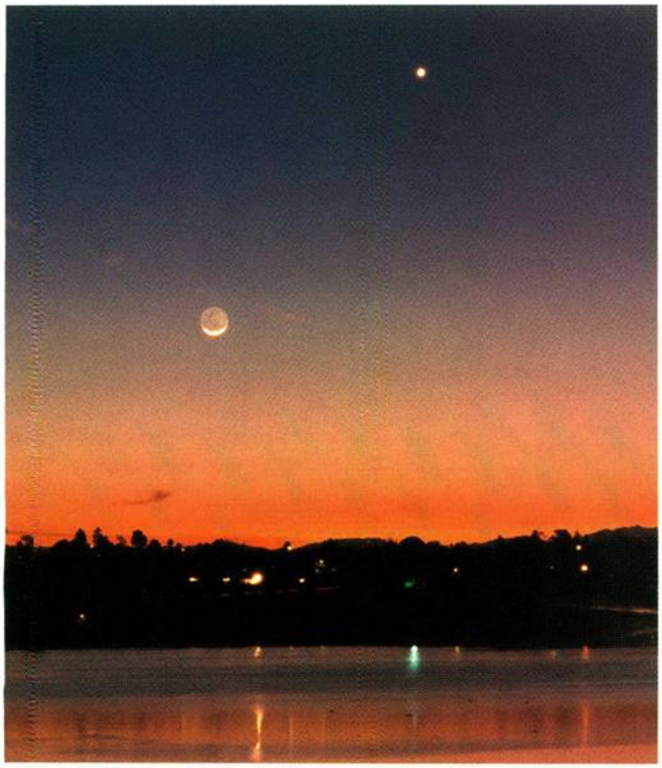
(8-inch SCT at f/60, Starlight Xpress CCD camera, composite exposure taken in Thessaloniki, Greece)



▲ **The Orion Nebula (M42)**

MATT RUSSELL

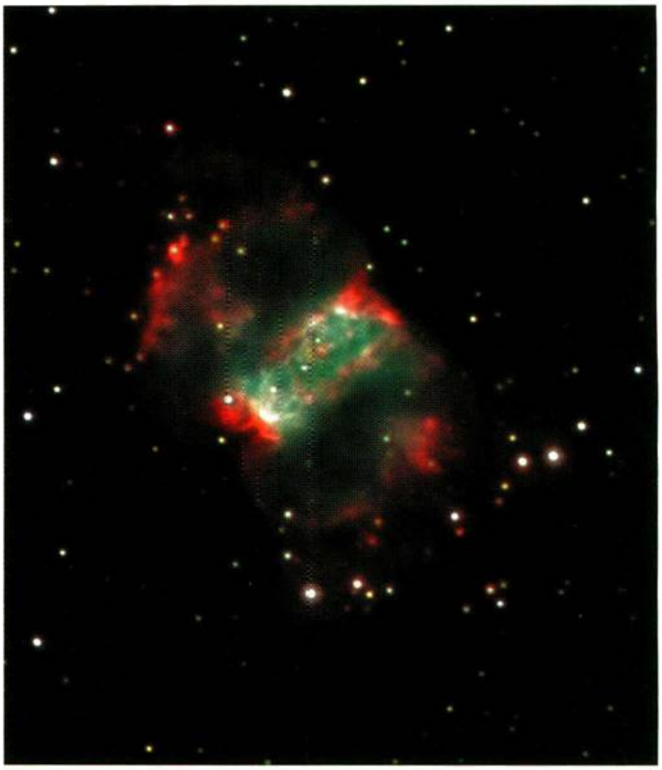
(11-inch SCT at f/6.3, SBIG ST-10XME CCD camera, composite of four 24-minute exposures)



▲ **Moon and Venus over Lake Murray, San Diego**

JERRY SCHAD

(85mm lens at f/4, Provia 400 film, 4-second exposure taken October 15, 2001)



▲ **The Little Dumbbell Nebula (M76)**

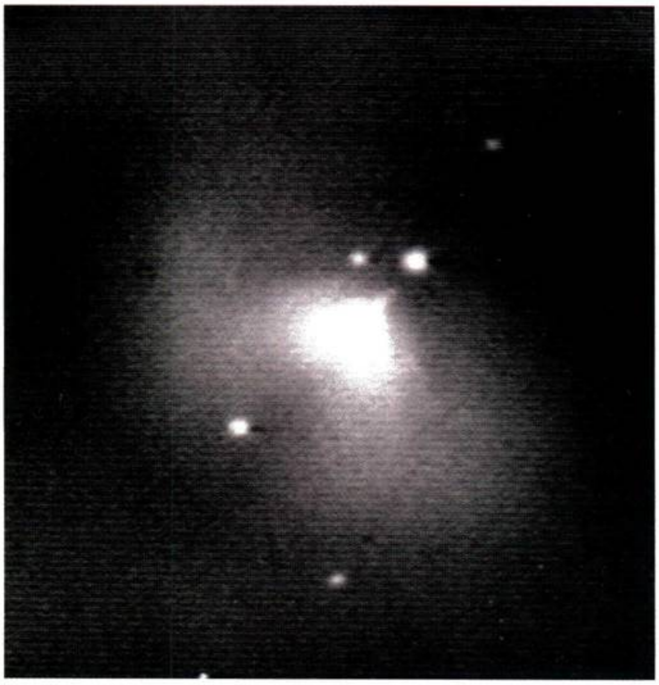
ROB GENDLER

(12.5-inch Ritchey-Chrétien scope at f/9, ST-10 CCD camera, composite exposure) spacecraft powered down, navigation for the emergency return to Earth would be anything but normal. NASA requested the most accurate spacecraft position data we could supply for navigation check and backup.

But how could we get better data than just setting circle readings off the telescope? I "borrowed" an oscilloscope camera from the Physics Department. I then used a combination of my Smithsonian star atlas with 60-second Polaroid prints. A fellow physics major and expert astronomer, Bob Amos, helped me crank out the data. The exercise went something like this: Find spacecraft, track with telescope, expose film, develop, identify stars, measure, calculate position, report to NASA, and repeat. We had an open phone line to NASA-Houston to report spacecraft positions. We were more than excited. But we didn't know if our work was of any help.

After their safe return home, the Apollo 13 astronauts visited Portland. Bob and I talked our way into a press conference to meet them. Exchanging a few words, I told them it was "nice to see them again." They were courteous, but we didn't seem to make any real connection. Had we been of any assistance? Perhaps we would never really know.

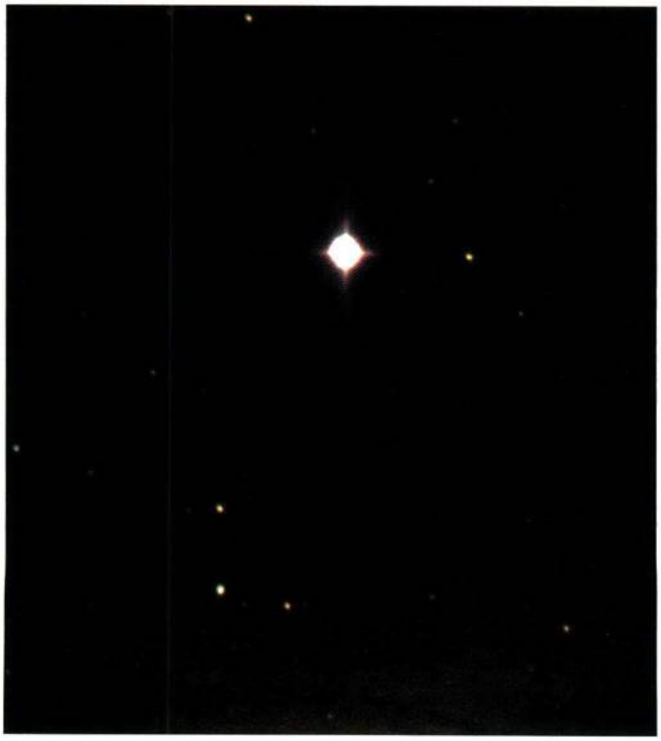
We continued to work with NASA on all the Apollo missions, Skylab, Soyuz, and other endeavors. In 1973 the Optical Tracking Group disbanded, and I went on to a career in the space program. While working at the Planetary Society's *Planetfest '97* event, I noted a talk about the Apollo 13 accident, but I was too busy to attend. The speaker was Dr. Hans Mark,



▲ Apollo 14 Spacecraft (with vented oxygen and hydrogen)

MICHAEL GILMORE

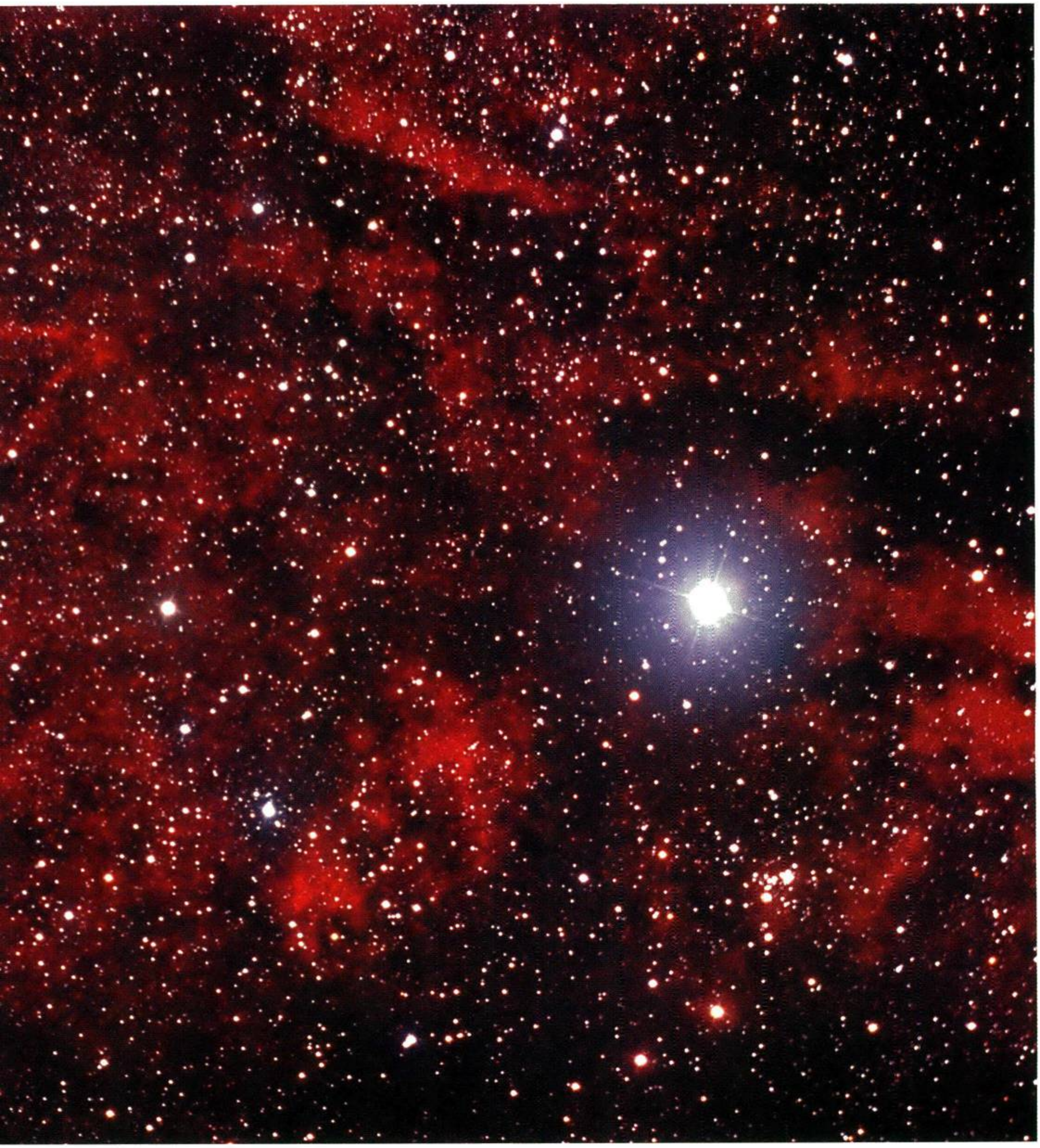
(24-inch reflector, 2-stage image intensifier video camera, taken at Pine Mountain Observatory in Oregon)



▲ Nova V4742 in Sagittarius

JOHN CHUMACK

(12-inch SCT, ST-8 CCD camera, taken September 22, 2002, in the Senoran Desert, Arizona)



▲ **Gamma Cygni Region (IC 1318, Sh2-108, B343, and LDN 889)**

JIM IVES

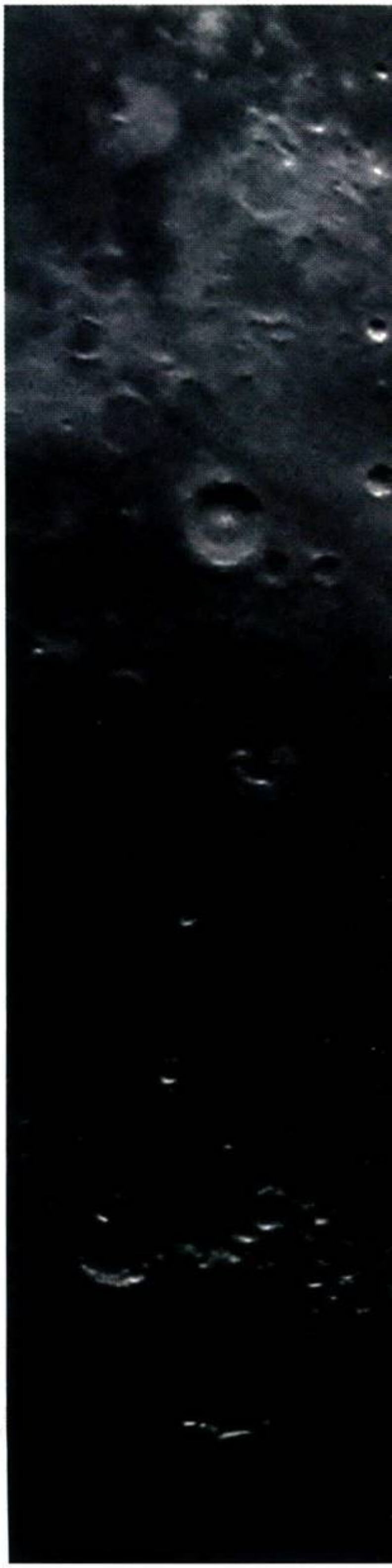
(20-inch reflector at f/3.3, PJ400 film, composite of two 45-minute exposures) a lead investigator into the Apollo 13 accident. Mark had been a key Apollo player as Director of NASA Ames Research Center and Deputy Administrator of NASA. Through a stroke of luck, I spotted Mark waiting for a ride. I asked him about Apollo 13 and Pine Mountain Observatory. "Pine Mountain, oh yes," he said. "Your observations, and that of a few other observatories around the world, were crucial to the Apollo 13 mission." A few more words and he was gone. But I finally had my answer. We had helped the astronauts of Apollo 13 find their way home. ▣

Michael Gilmore is a veteran of the space program and Fellow of the British Interplanetary Society.

▲ **M69 in Sagittarius**

AL KELLY

(8-inch SCT at f/5, Starlight Xpress CCD camera, composite exposure taken October 6, 2002)



▲ **Aurora over Canada**

LAWNY FELSKE

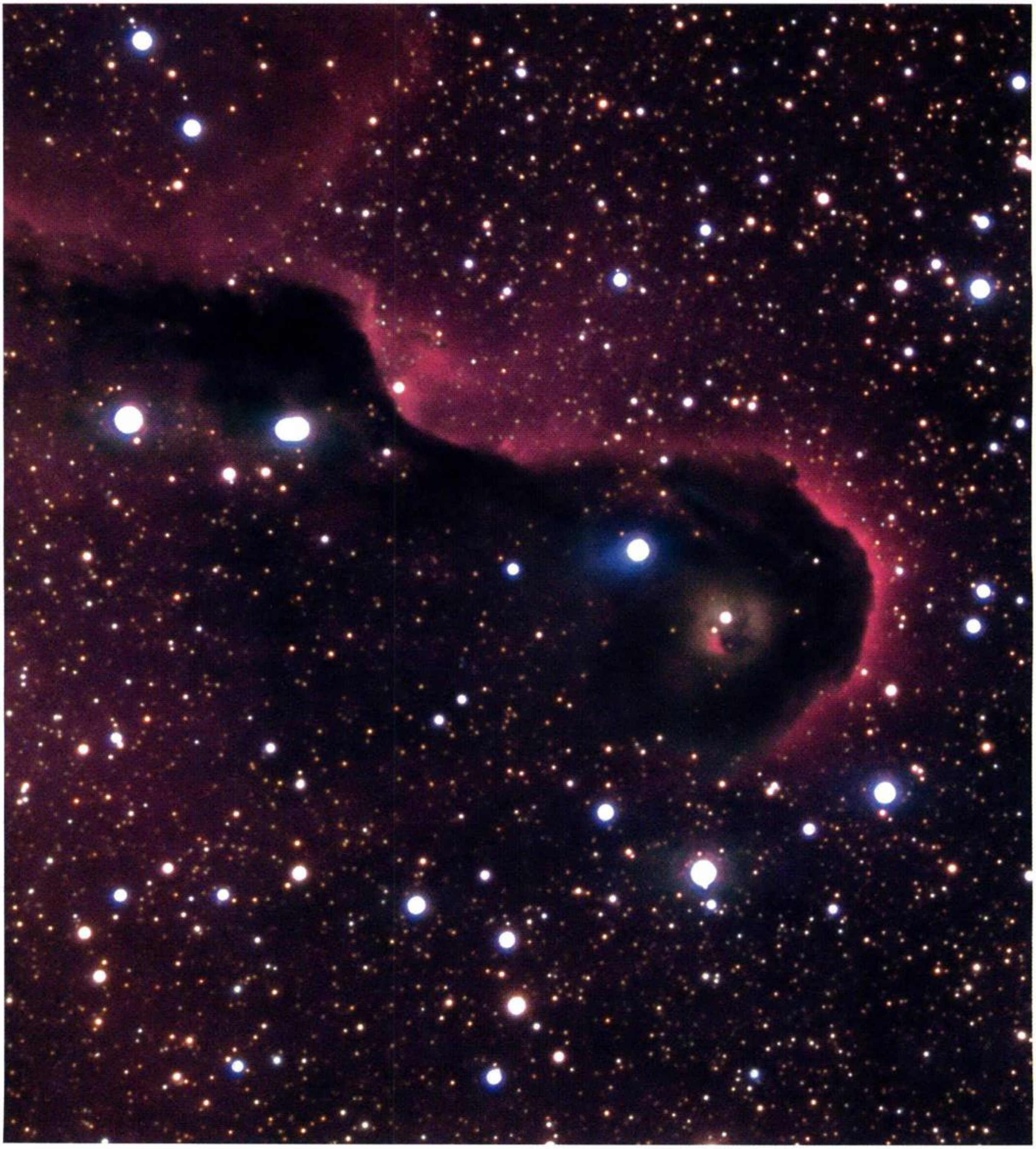
(28mm lens at f/2.5, Fuji Superia 800 film, 30-second exposure taken October 1, 2002, in Breton, Alberta, Canada)

▲ **The Moon**

RALF VANDEBERGH

(6-inch apochromatic refractor, Fuji digital camera)

This month's best astrophoto



▲ **Reflection Nebula VDB 142**

GARY STEVENS

(11-inch SCT at f/10, SBIG ST-8E CCD camera, composite exposure taken September 7, 2002, in Mt. Pinos, California)

This unique reflection nebula is embedded in the much larger emission nebula IC 1396 in Cepheus.

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